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THE INFLUENCE OF CATIONS UPON BACTERIAL VIABILITY

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THE PHENOMENA OF SALT ANTAGONISM

STUDIES conducted by numerous investigators in widely separated fields of biology have revealed an interesting series of phenomena, associated with the influence of mineral salts on vital processes. The investigations of Ringer, Loeb and others on the contractility of muscle, of Loeb, Ostwald and others on the viability of *Fundulus*, *Gammarus*, Tubularians, Medusae and other marine animals, of Loeb on the development and specific gravity of *Fundulus* eggs, of Osterhout and his colleagues on viability of algae, germination of wheat embryos, electrical resistance of *Laminaria* and plasmolysis of *Spirogyra*, are outstanding examples in this field. Loeb, Feen, Clowes and others have observed roughly analogous effects produced upon the electrical resistance, swelling, osmotic pressure and alcohol number of gelatin or of artificial soapy membranes. Loeb (1) fully reviewed the earlier history of the subject and Falk (2) has presented an exhaustive review of the literature, particularly in regard to the effects of salts upon bacteria but with reference to other forms of life as well.

The most striking result of these studies has been the demonstration that electrolytes of bivalent cations are generally much more toxic (or otherwise effective) than those of univalent cations. Furthermore, in practically all the instances cited above, bivalent and univalent cations antagonize each other, the optimum solution being as a rule one which contains about 20 parts of Na to one part of Ca.

In discussing the antagonistic influence of salts on animal tissues and on algae and higher plants, it has generally been assumed that the phenomena were related to specific individual properties of the different ions involved. Thus, Loeb (3) attributed the swelling of protein caused by dilute NaCl to the formation of an ionizable protein salt and the neutralizing influence of $CaCl_2$ to the production of a non-ionizable salt. Osterhout (4) similarly assumed a specific increase of permeability of plant cells to be caused by Na as such and a decrease to Ca as such.

In the field of bacteriology, the chief studies on salt antagonism have been reviewed by Winslow and Dolloff (5). These investigations have covered viability of various species of pathogenic and soil

bacteria, biochemical activity (ammonification, nitrification, nitrogen fixation) and electrical resistance. The evidence for antagonism is, on the whole, less clear in these experiments than in those conducted with algae or animal tissues. In general, however, it appears that, here also, dilute Na solutions tend to favor viability and biochemical activity while a corresponding concentration of Ca produces an opposite effect. Mixtures of a monovalent and a bivalent salt, or of two univalent salts were found to be more favorable than either one alone by Eisler, Lipman and his associates, Shearer, Brooke, and Winslow and Falk. The antagonistic effect was manifest in solutions containing from five to twenty times as much Na as Ca.

VARIATION IN SALT EFFECTS WITH VARYING CONCENTRATION OF A GIVEN SALT

That such effects of salts are by no means always specific and qualitative in nature is clearly indicated on a careful survey of the literature. In such widely separated phenomena as the viability of various marine invertebrates, the development of *Fundulus* eggs, the biochemical activity of bacteria, various reactions of gelatin and certain enzyme hydrolyses and syntheses, it appears:

a. That solutions containing single pure salts in very low concentrations are more favorable than distilled water to biological and physico-chemical processes; while

b. Stronger concentrations of the same salts exert a precisely opposite effect.

In the case of bacterial viability, this phenomenon has been demonstrated with special clarity.

Hotchkiss (6) studied the effect upon *Es. coli* of twenty-three different chlorides in varying concentration. In every instance she found the salt toxic at a certain concentration (varying from 2.0 M with NaCl and KCl to 0.00001 M with $HgCl_2$); but in the case of fifteen of the twenty-three salts she found a lower concentration (ranging from 0.25 M with NaCl and KCl to 0.000001 M with $HgCl_2$) which was definitely stimulating in its effect. There was no reason to believe that a stimulating concentration could not have been found in the other eight salts if more dilutions had been employed. This work was continued by Winslow and Falk (7), Winslow and Dolloff (8) and Winslow and Haywood (9) with completely confirmatory results.

Table 1 shows comparative results obtained in four distinct series of experiments in four different culture media,—the viability of *Es. coli* being the phenomenon observed in each case. Results differ somewhat in different media as would be expected, slightly higher concentrations being required to produce a given effect in the presence of more complex organic substances. In general, however, the coincidence is fairly close except in the case of $HgCl_2$.

Winslow and Haywood studied the zone of stimulation in greater detail and obtained the results indicated in Fig. 1. The organism observed was the same strain of *Es. coli* used in previous experiments and the culture solution was the Dolloff synthetic medium (10). The salts were all chlorides. Bacterial numbers at the end of 48 hours are expressed in percentages of the number present in a salt-free control. The abscissa scale is a logarithmic one to make comparison of the different salts possible. It is the same in all diagrams and to emphasize the difference in quantitative effect, the abscissa corresponding to 0.001 molal concentration is indicated by a heavy line.

The general phenomenon involved,—the stimulation of bacterial growth by low concentrations of salts and its inhibition by higher concentrations,—has been re-

corded by numerous other observers. It seems clearly demonstrated that all cations (even including such highly toxic substances as $HgCl_2$, Pt Cl_4, $AuCl_3$, Cd Cl_2, $CeCl_2$, $PbCl_2$, $CoCl_2$, and $AlCl_3$) are stimulating to bacterial growth in sufficiently low concentration; and that all cations (even including such ordinarily favorable substances as NaCl and KCl) are toxic in sufficiently high concentration.

TABLE 1

Critical Concentrations of Various Salts as Determined by Different Investigators in Various Media

SALT	MEDIUM	OBSERVER	STIMULATING CONCENTRATION	SLIGHTLY TOXIC CONCENTRATION	HIGHLY TOXIC CONCENTRATION
			M	M	M
NaCl	Water	Winslow and Falk	0.014–0.145	0.43	0.7
	Tartrate	Winslow and Dolloff	0.025–0.300	0.40	0.6–0.7
	Pepton	Hotchkiss	0.025–0.250	0.50	2.0
KCl	Water	Holland	0.145–0.436		0.7
	Tartrate	Winslow and Dolloff	0.050–0.400	0.50	0.8
	Pepton	Winslow and Dolloff	0.250	0.75	1.0
	Pepton	Hotchkiss	0.250	0.50	2.0
$CaCl_2$	Water	Winslow and Falk	0.001–0.140		0.4
	Pepton	Winslow and Dolloff	0.050–0.070	0.10	0.2
	Pepton	Hotchkiss	0.050–0.250		0.5
$MgCl_2$	Water	Holland	0.020–0.080		0.5
	Tartrate	Winslow and Dolloff	0.003–0.070	0.10	0.2
	Pepton	Hotchkiss	0.050–0.100		0.5
$BaCl_2$	Asparagin	Winslow and Dolloff		0.10	0.2
	Pepton	Hotchkiss	0.050	0.10	0.2
$PbCl_2$	Asparagin	Winslow and Dolloff	0.0000001	0.0001	0.0005
	Pepton	Hotchkiss	0.00005		0.0005
$HgCl_2$	Tartrate	Winslow and Dolloff	0.00000001–0.00000005		
	Pepton	Winslow and Dolloff	0.00000001	0.00000005	0.0000005
	Pepton	Hotchkiss	0.000001	0.000005	0.00001

THE CONCEPT OF SPECIFIC POTENCY

These investigations in the field of bacterial physiology have opened the way to a second important generalization. Winslow and Dolloff, five years ago (11) showed that, if one compares the effect of one cation with that of another, there is a definite quantitative relationship between all points on the graph of viability at varying salt concentration. In other words, if the concentration of salt A which produces a given degree of stimulation is called x and the concentration of salt B which causes the same degree of stimulation is 10 x; and if the concentration of salt A which produces a given degree of inhibition is 5 x; then, the concentration of salt B which should cause this same degree of inhibition is 50 x.

In Fig. 2 for example the upper half of the graph shows the curve for NaCl, the

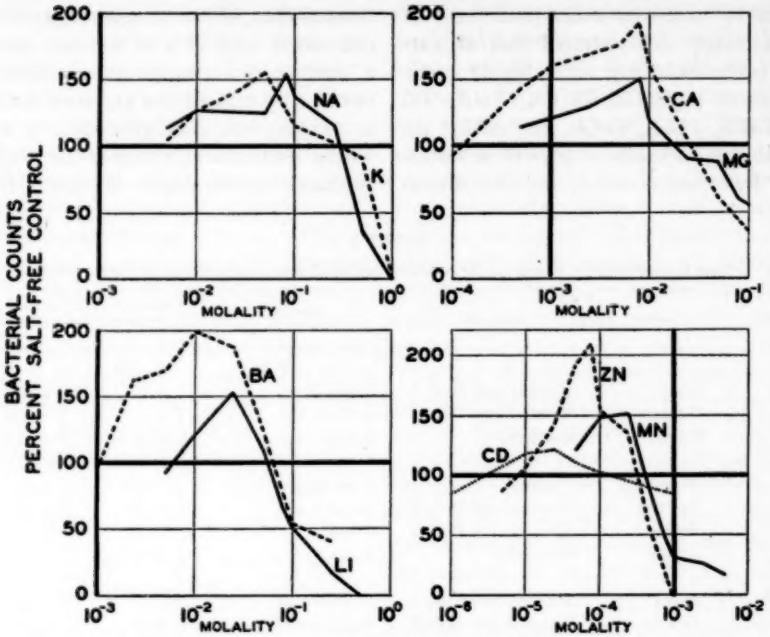

FIG. 1. RELATION BETWEEN CONCENTRATION OF VARIOUS CHLORIDES AND SURVIVAL OF BACTERIA IN A SIMPLE SYNTHETIC MEDIUM

Ordinates represent number of bacteria present expressed as percentages of the number present in salt-free control. Abscissae represent concentrations of salts on a logarithmic scale. Abscissa corresponding to 0.001 molal solution indicated by heavy line.

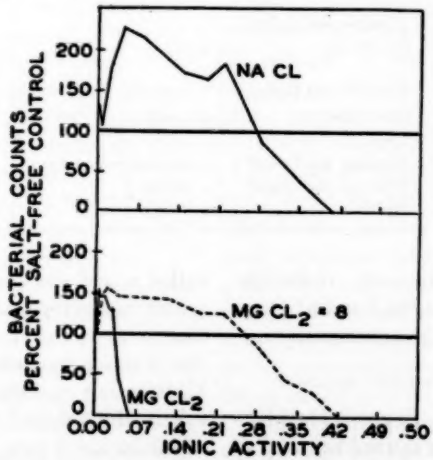

FIG. 2. VIABILITY OF BACTERIA IN CHLORIDES OF SODIUM AND MAGNESIUM OF VARYING STRENGTH

Ordinates represent number of bacteria present expressed as percentages of the number present in salt-free control. Abscissae represent computed ionic activities.

abscissae representing salt concentration in terms of ionic activity (computed from the tables of Lewis and Randall) on a direct and not a logarithmic scale, the ordinates, bacteria present after 18 to 20 hours in percentages of the number present in a salt-free control. The solid line in the lower half of the graph shows the effect of $MgCl_2$ in the same way. The dotted line in the lower section shows the curve for magnesium plotted with each concentration of $MgCl_2$ multiplied by eight. It will be noted that this dotted curve closely resembles the NaCl curve above. In other words $MgCl_2$ is approximately eight times as powerful as NaCl, both in the stimulating and in the inhibiting zone.

In a later study by Winslow and Haywood (12) curves were determined in detail for nine different cations. Cultures of *Es. coli* were grown in the Dolloff synthetic medium for 48 hours at 37°. In the medium without added salt, bacterial numbers rose from 20–50 million per cubic centimeter to over 200 million per cubic centimeter. With added increments of various chlorides, the numbers rose above those for the salt-free control in dilute solutions and fell off sharply in stronger solutions. The final counts for each salt solution expressed as percentages of the salt-free control are presented in Table 2. They are the same results plotted in Fig. 1 above.

From the curves thus plotted, eight arbitrary points were selected as follows: in the zone of increasing stimulation, the point where the count was 25 per cent in excess of the salt-free control and the midpoint of the zone as a whole; the point of maximum stimulation; in the zone of de-

TABLE 2

Survival of Bacteria in Salt Solutions of Various Strengths as Compared with Salt-Free Control (Per Cent)

MOLALITY	NaCl	KCl	LiCl	$BaCl_2$	$MgCl_2$	$CaCl_2$	$MnCl_2$	$ZnCl_2$	$CdCl_2$
1.0	0	0							
0.5	37	91	0						
0.25	115	102	16	40					
0.1	137	115	51	54	56	36			
0.08	154		66		61				
0.05	125	155	111	123	87	62			
0.025		140	156	187	89				
0.01	127	127	121	199	119	159			
0.008					149	192			
0.005	113	104	93	170	140	176	15		
0.0025				162	128		25		
0.001				96	121	159	28	0	84
0.0008							46		
0.0005					114	142	87	57	87
0.00025							151	135	
0.0001						93	147	154	102
0.00008							137	208	104
0.00005							120	191	111
0.000025								142	121
0.00001								105	117
0.000005								85	91
0.000001									83

creasing stimulation, the point showing a count 50 per cent above the control and the point showing a count 25 per cent above the control; the cross-over point where, with a rather high salt concentration, counts were again equal to those of the control; and, in the zone of toxicity, the points showing counts equal to 75 per cent and 50 per cent of the control, respectively. For each of these eight points on the curve of viability, we read off the corresponding salt concentration. The concentration of NaCl producing a given effect was taken as 1, and the concentration of the other salts producing the same effect was expressed as a reciprocal of its ratio to the corresponding concentration of NaCl. Thus, for example, maximum stimulation was produced by NaCl in 0.08 M concentration and by $BaCl_2$ in 0.01 concentration. The reciprocal of this relationship is 8.

TABLE 3

Specific Potency of Various Cations

	ZONE OF INCREASING STIMULATION		MAXIMUM	ZONE OF DECREASING STIMULATION		CROSS-OVER POINT	ZONE OF TOXICITY		AVERAGE
	Percentage of salt-free control								
	125	Midpoint		150	125	100	75	50	
Na	1	1	1	1	1	1	1	1	1
K	1	1	1.6	1.8	2.1	1.0	0.5	0.6	1.2
Li	0.9	1	4.0	3.0	4.3	4.7	5.1	4.4	3.4
Ba	9	5.0	8.0	2.3	3.4	4.7	4.5	3.4	5.0
Mg	4.5	5.0	10	11	17	14	5.1		9.4
Ca	30	17	10	9.0	8.5	9.3	9.0	6.3	12.0
Mn	150	170	400	300	600	700	600	600	400
Zn	450	250	1,000	900	600	900	900	900	700
Cd		1,200	4,000			2,800			3,000

Table 3 indicates these relationships. There is considerable variation in the different columns for the same salt as would be expected from a method involving the reading of arbitrary values on a curve plotted from a few points. Furthermore, in this study molal concentrations and not specific ionic activities were used. Nevertheless, the harmony of the results is much more striking than their irregularities; and the last column, representing an average of the eight columns to the left of it, corresponds closely with the results of other investigations. Thus, for example, the studies reported in 1928 indicated that $MgCl_2$ was eight times as powerful as NaCl or KCl. Here, the ratio is 1 for NaCl, 1.2 for KCl and 9.4 for $MgCl_2$. It seems reasonable to conclude from these results and those of other workers that all cations exert upon bacterial viability a certain influence (aside from other possible influences) which is qualitatively the same. "The quantitative effect of different cations varies very widely but each has a specific efficiency, both as regards stimulation and inhibition. This characteristic, we have designated as 'specific potency.'"

The specific potencies of the cations studied by Winslow and Haywood were found to be as follows, taking the potency of Na as 1: K, 1.2; Li, 3; Ba, 5; Mg, 9; Ca, 12; Mn, 400; Zn, 700; Cd, 3000. This general order of specific potency has recently been confirmed for aerobic sporeformers by Fabian and Bryan (33).

There was some indication in the work of Winslow and Dolloff that even the hydrogen ion may fit into the same general principle, with a specific potency some 30,000 times that of Na.

QUANTITATIVE AND QUALITATIVE SALT ANTAGONISM

The demonstrated fact that each cation may exert either a stimulating or an inhibiting effect,—depending on its concentration,—must obviously be taken into consideration in studies of so-called "salt antagonism." In any mixture of salts we must, first of all, consider what results might be expected from the purely additive effect of the cations present,—with due allowance for the specific potency of each. The investigation reported by Winslow and Dolloff (13) attempted to deal with this question by studying the influence of NaCl and KCl in combination with $MgCl_2$. It showed first of all, that when $MgCl_2$ was mixed with either of the univalent salts in a proportion of 1:10 the effect of varying concentrations of the mixture was exactly what would be expected on the basis of purely additive effects. That is, if a $2x$ concentration of NaCl produced a given stimulating effect, that same effect would be produced by a mixture of x NaCl + $x/8$ $MgCl_2$,—the specific potency of $MgCl_2$ being taken as approximately 8. The curve for a mixture of KCl or NaCl and $MgCl_2$, if the actual amount of $MgCl_2$ was multiplied by 8, the actual amount of NaCl added and the sum used for an abscissa, was exactly like the curve in Fig. 2 for NaCl alone. We were dealing here with the sort of ratio (1 part of a bivalent salt to 10 parts of a univalent salt) supposed to show salt antagonism. Yet the effects are seen to be purely additive in nature.

When the total molality was kept constant at 0.5 molal concentration, but the proportion of NaCl or KCl and $MgCl_2$ was varied, quite similar results were observed. There were certain points on the curve where a suggestion of possible specific qualitative antagonism was obtained; but, in general, the results were exactly what would be expected from a summation of the effect of each salt taken by itself.

Winslow and Haywood (14) attempted to put the specific potency theory to a crucial test by mixing NaCl in five different proportions with each of seven other chlorides and then repeating the process with $CaCl_2$, mixed in five proportions with each of six other salts. Each admixture should, on the theory of additive specific potency, have produced a count equal to that of the salt-free control (corresponding to the "cross-over point" at which the descending curve cuts the 100 per cent line in Fig. 1). With NaCl and all the salts mixed with it the results were close to expectancy. Out of thirty-five mixtures all but two showed counts between 75 and 125 per cent of the salt-free control. $CaCl_2$ mixed with either KCl, $MgCl_2$ or $MnCl_2$ gave similar results. Mixtures of $CaCl_2$ with $BaCl_2$ on the other hand yielded results higher than would be expected (118–167 per cent of the control); while $CaCl_2$ mixed with LiCl and $ZnCl_2$ gave results lower than the theory would warrant (37–65 per cent of the control).

These last observations furnish a salutary warning against any generalization which tends to oversimplify the phenomena of salt action. Yet it seems clear that the phenomenon of specific potency and the results of additive effects must be taken into account before assuming "antagonism" in the sense of a specific qualitative neutralization by one salt of the specific qualitative influence of another salt.

In interpreting the effect of salt mixtures we must also be quite clear as to the differ-

ence between mixing two salt solutions of known strength (which involves dilution of each) and the addition of solid salt to a solution of another salt (which does not involve dilution). It is obvious that if we take two different concentrations of the same salt and mix them the effect will be the same as that of an intermediate concentration. What that result will be, however, will depend on the particular part of the potency curve at which the concentrations used may lie. Thus from Fig. 1, it appears that if we mix two concentrations of NaCl, both of less than 0.05 M strength, we shall get a stimulating effect intermediate between that of the two concentrations used (since both lie in the zone of increasing stimulation). If, however, we mix a concentration lying in the zone of increasing stimulation (say 0.01 M) with a concentration in the zone of decreasing stimulation (say 0.1 M) we shall obtain a greater stimulation than that given by either primary concentration alone since the mixture will correspond to the point of maximum stimulation. If we mix a concentration lying in the zone of diminishing stimulation (say 0.1 M) with a concentration in the zone of toxicity (say 0.44 M) we shall obtain a neutralization of effects. The last two are just the sort of phenomena often described as antagonism when two salts are used. Yet with one salt alone it is clearly not antagonism but addition which is taking place. The results here discussed show that when different salts are used the phenomena often follow the same law and, when they do so, the assumption of antagonism is superfluous.

In other studies of so-called antagonism, instead of mixing two salt solutions (and thus diluting each) a second salt is added to a solution of the first salt, keeping the concentration of the first unchanged. Here the problem is simpler but the result will still be largely determined by the part of the specific potency curve in which the addition takes place.

Thus, if we start with a salt concentration lying in the zone of increasing stimulation the addition of a small amount of another cation will push the total cation concentration up to the point of maximum stimulation. A larger addition will carry the total concentration over to the zone of decreasing stimulation or the zone of toxicity. If we start with a salt concentration giving maximum stimulation the addition of any other cation will carry the total concentration into the zone of decreasing stimulation or toxicity; so that starting at this point any salt will appear antagonistic to any other salt, even if the concentration of the second salt added were itself stimulating in effect.

The only thing that cannot occur according to the principle of specific potency is the neutralization of toxic effect by the actual addition of any cation to a solution already toxic (without dilution). This is the critical test, since according to the uncomplicated effects of specific potency, the addition of any amount of a second cation should increase the toxic effect of the first.

One of the clearest cases of such true antagonism was presented by Winslow and Falk (14) with regard to Na and Ca. Solutions of 0.6 M NaCl and 0.1 M $CaCl_2$ were highly toxic but a solution containing both these salts in approximately the same concentration was non-toxic. In a later paper the same authors showed that this phenomenon only occurred in alkaline solutions and was related to the influence of calcium on the power of the cell to buffer the adjacent medium, which influence was eliminated by NaCl (Winslow and Falk, 15).

Eisler (16), Lipman (17), and Brooks (18) have all reported results of this kind,

which seem to indicate true qualitative antagonism of salts in their influence on bacterial viability. On the other hand, such observations as those of Shearer (19) can readily be explained as due to additive effects.

Whatever more complex and specific qualitative effects may be superimposed thereon, it seems clear that there is a fundamental and qualitatively similar influence exerted by all cations upon the bacterial cell. This influence takes the form of stimulation of viability when the cation is present in low concentration and of inhibition when it is present in higher concentration; and each cation has a certain specific potency which determines its quantitative influence. Only when due allowance has been made for the direct additive results of the cations present operating according to their characteristic potencies, can true antagonism be postulated.

How far this same principle may apply to higher forms of life, we cannot say; but it seems highly desirable that the possibility of similar influences should be borne in mind. The results obtained by Loeb with marine animals and by Osterhout with Algae seem to offer close parallelisms with those observed in our bacteriological studies.

THE INFLUENCE OF ANIONS

It would be obviously incorrect to assume that the influence of salts upon bacterial viability is entirely due to the effect of the cations involved. In many instances, we know that the anion is important; while in other cases the undissociated salt is specifically active.

The literature of anion effects has not been voluminous but considerable work has been done on the hydroxyl ion, much of which has been summarized in a study by Fabian and Winslow (20). This investigation was designed to be complementary to the earlier studies from this laboratory in which the effect of various cations in combination with a single anion (Cl) was observed. Here, on the other hand, Na was employed as the uniform cation. The compounds tested were NaOH, Na_2CO_3, Na_3PO_4, $NaHCO_3$, Na_2HPO_4, NaCl, Na_2SO_4, NaH_2PO_4 and mixtures of the same salts with NaOH,—fifteen different solutions in all. For each solution seven to eighteen different concentrations were studied, the whole study involving the pouring of approximately 3700 plates.

All of the solutions gave us graphs generally similar to those in Figs. 1 and 2. The concentration of Na producing a stimulating effect was essentially the same whatever the anion might be (between 0.001 and 0.10 molal for 25 per cent stimulation). In the zones of decreasing stimulation and toxicity, however, NaOH, Na_2CO_3 and Na_3PO_4 with their mixtures were highly potent and approximately of the same order of magnitude while the other five substances, $NaHPO_4$, $NaHCO_3$, Na_2HPO_4, NaCl and Na_2SO_4, required from 20 to 100 times the same concentration to produce a given effect.

These results obviously suggested that hydrogen-ion concentration was the second major factor in the situation. To test this, we prepared a graph which has been redrawn in Fig. 3. In this graph, ordinates represent logs of molal concentration of sodium and abscissae represent pH values (logs corresponding inversely to molal concentration of hydrogen). In the original graph, from which Fig. 3 has been simplified, the average bacterial count (in per cent of the salt-free control) was written down at the appropriate point, for each of 158 salt mixtures studied, irrespective of the alkali or salt concerned. After this was done, as may be seen by reference to the original paper, the numbers on the chart grouped themselves in a very definite

way, the highest numbers near the upper right hand corner and the lower numbers in reasonably regular descending order as one passed outward from this area. It was possible to draw lines about each of five areas with considerable accuracy,—and these five areas are shown by cross-hatching in Fig. 3. In Area I, there were three solutions, all exhibiting an increase of 500 per cent or more as compared with 100 per cent in the salt-free control. Area II included twelve solutions showing 100–500 per cent increase, three showing 50–100 per cent increase and two showing 0–50 per cent increase. Area III included three solutions showing 100–500 per cent increase, twenty-four showing 50–100 per cent increase, thirteen showing 0–50 per cent increase and three showing a decrease. Area IV included one solution showing 50–100 per cent increase, forty-two showing 0–50 per cent increase and five showing a decrease. Area V included five solutions showing 0–50 per cent increase and forty-two showing a decrease.

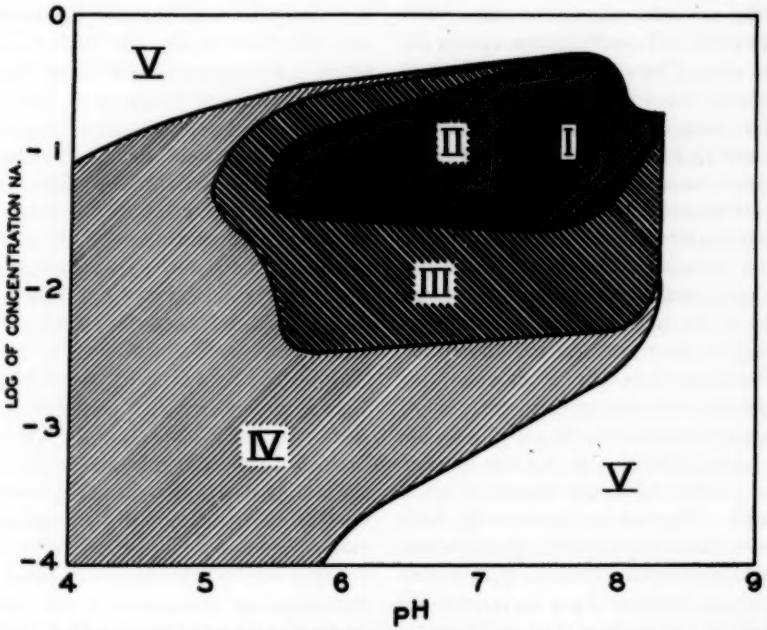

FIG. 3. GRAPH INDICATING THE SIMULTANEOUS EFFECT OF SODIUM IONS AND HYDROGEN ION CONCENTRATION UPON BACTERIAL VIABILITY, WITH 158 DIFFERENT MIXTURES OF NaOH AND OF SEVEN SODIUM SALTS

Ordinates represent total molal concentrations of sodium in these mixtures. Abscissae represent hydrogen ion concentration as pH.

The shaded areas represent bacterial viability. In Area I all counts showed an increase of 500 per cent or more as compared with the increase in the salt-free control taken as 100 per cent. In Area II most counts were between 100 and 500 per cent of the increase in the salt-free control; in Area III between 50 and 100 per cent of the increase in the salt-free control; in Area IV less than 50 per cent of the increase in the salt-free control; while in Area V nearly all observations showed a decrease in bacterial numbers instead of an increase.

This type of diagram is of very grert value since it makes it possible to observe the simultaneous influence of two more or less independent variables. Lawrence Henderson has applied a somewhat similar

principle in his studies of blood chemistry and has shown how much more significant such an analysis may be than the ordinary approach which considers but one variable at a time. Figure 3 may be interpreted in terms of a topographical map. If a layer of cardboard half an inch thick were over the whole chart, a second layer of cardboard cut to correspond to area IV, and placed on the first, a third layer cut out to correspond to area III and placed on top of the second, and so on,—we should get a relief map of a mountain with its peak in Area I, a very sharp declivity toward high pH values and high Na values and a very gentle slope toward low Na and pH values.

The correlation was not, of course, perfect and the exceptions are themselves highly significant. Of the nine solutions which showed results higher than would be expected for their sodium and hydrogen ion content, seven were phosphate solutions. Furthermore, all of the nine points in areas I and II showing an increase of over 200 per cent in bacterial count were obtained with mixtures of Na_2HPO_4. Thus, it appears probable that the phosphate radicle exerts a specific stimulating effect. Similarly, of thirteen solutions which showed results markedly lower than would be expected, eight were carbonate solutions which may perhaps have a specific inhibitory effect.

In general, however, the main influences seem clearly to be Na concentration and hydrogen ion concentration. Maximum stimulation occurs with a sodium concentration of 0.10 M and a pH of 7.5. Decrease of Na concentration and decrease of pH value below this optimum result in a gradual diminution of stimulating effect. No doubt a further decrease of pH would have ultimately caused a sharp inhibition but we had no observations in the area of very low Na concentration and very low pH.

An increase in Na or pH in the zones studied caused a much more rapid change from stimulation to inhibition, Na concentrations above 0.6 M and pH values above 8.3 being definitely inhibitive.

It appears clear that two major factors govern bacterial viability under the conditions of these experiments. The first is the cation concentration, the effect of all cations (according to our earlier studies) being qualitatively alike and differing in accordance with their specific potency. The second factor is the pH which, with a given cation, is determined by the anion present. The phosphate, and perhaps the carbonate, radicles exert specific influences which are superposed upon the two primary effects indicated.

THE MECHANISM OF SALT ACTION

In the studies of salt antagonism with higher plants and animal cells there has been a general indication that salts favorable to biological processes increase permeability while toxic salts decrease it. Falk (21) summarizes the evidence as follows:

> In their effect upon electrical resistance [of *Laminaria*, frogskin or bacteria] bivalent cations like Ca show a characteristic tendency to cause first an increase and then a decrease in resistance, while univalent cations like Na show a uniform fall. The decrease of resistance in the two cases when it does occur, seems however to be different in nature, being irreversible in the case of the bivalent salt and reversible (if exposure has not been too prolonged) in the case of the univalent cation. The effect exerted by electrolytes appears to be primarily an effect upon external or internal membrane surfaces and upon surface interphases in colloidal systems. This is clearly demonstrated by the influence of unbalanced solutions upon the specific gravity of *Fundulus* eggs, and *Fundulus* body fluids, and upon the plasmolysis of *Spirogyra* and is strongly suggested by the changes in the electrical resistance of plant and animal tissues,

bacterial emulsions and artificial membranes. Where effects upon permeability are clearly manifest, Ca and other bivalent cations usually decrease permeability, while Na and the univalent cations always tend to increase it. We may interpret Loeb's experiments on *Fundulus* eggs as showing a decrease in permeability due to Ca; while all Osterhout's work on electrical resistance of plant and animal tissues as well as Shearer's on electrical resistance of meningococci show a preliminary decrease due to calcium followed by an increase (which is probably a wholly different phenomenon from the primary fall in resistance due to Na).

Evidence in this direction is by no means altogether harmonious. In particular, Irwin (22) in studying the effect of salts upon the penetration of dyes into the vacuole of *Nitella* found that preliminary treatment with 0.03 M NaCl decreased the subsequent penetration of dyes into the treated cells while bivalent cations had no such effect. When the salt and the dye were simultaneously present, however, 0.03 NaCl and 0.003 $MgCl_2$ and $CaCl_2$ slightly increased penetration. The latter effect is what one should expect on the theory of specific potency. In general, however, the work of Brooks (23) with dandelion tissue, of Shearer (24) and Winslow and Falk (25) with bacteria and of Osterhout (26) with *Laminaria* all tend to show that in given concentration Na increases and Ca decreases permeability; while Endler (27) demonstrated that dilute electrolytes increase and stronger electrolytes hinder diffusion in the case of green algae.

A comprehensive study of this problem has been made by Shaughnessy and Winslow (28) in order to determine the effect of various dilutions of salts upon the diffusion of certain substances outward from the bacterial cell in menstrua of varying salt content. Three types of bacterial material were studied, cells of *Es. coli* which survive in practically undiminished numbers under the conditions of the experiment, heat-killed cells of the same organism and cells of *Bact. cereus* which die out almost at once in a medium lacking protective colloids. Heavy suspensions of these cells were placed in the menstrua to be tested and after exposure for selected periods up to 24 hours the cells were removed by centrifugation and tests were made for various substances in the supernatant liquor.

This study showed that marked changes take place in the menstrua surrounding either living or dead bacterial cells as a result of diffusion outward from the interior of the cells. Under conditions of normal physiological activity, these changes are of a protective nature, involving the liberation of acidic substances (CO_2) in alkaline or neutral media and of alkaline substances (NH_3) in a more acid medium in such a way as to maintain an approximate pH of 6.2–6.4. On more prolonged exposure to an unfavorable menstruum the production of ammonia overbalances that of CO_2,—a reaction characteristic of injury. Dilute solutions of NaCl (0.0145–0.145 M) tend to increase the diffusion of ammonia, carbon dioxide, chlorides and phosphates whether in the presence of living or dead cells. Stronger salt solutions (1.45 M NaCl and 0.0145–0.145 M $CaCl_2$) decrease the liberation of ammonia. Finally, a still stronger calcium solution (1.450 M) shows a sharp rise in titratable products in the menstruum followed by a fall. This sharp rise is attributed by the authors to a decrease in permeability so great as to lead to lysis of the cells and liberation of protein, or to a special type of membrane coagulation. The subsequent fall may be due to accumulation of non-reactive films on the protein micellae or to absorption of oppositely-charged ions.

The point in which we are here chiefly concerned is best illustrated by the results

for ammonia nitrogen cited in Table 4. It will be noted that diffusion is greatest with *Bact. cereus* (as would be expected from its great susceptibility to osmotic influences) and least in the heat-killed cells of *Es. coli*. In all instances, however, the dilute salt increased diffusion and the strong salt abolished it completely.

Since this phenomenon appeared with the cells of *Bact. cereus* (which we know die almost at once in such a menstruum (29)), and with the heat-killed cells of *Es. coli*, it seems clear that it is related not to the formation of new materials by metabolism but to some process governing diffusion from the interior to the exterior of the cell wall. Whether this process directly affects the permeability of the cell wall itself or operates through influences on the electrolyte balance inside or out, we cannot affirm with any certainty.

The conclusions from this study were fairly clear, since the salt concentrations favorable and unfavorable to diffusion were those which in other studies had been found favorable and unfavorable, respectively, to viability. No bacterial counts were made, however, in the actual studies reported in 1927. Recently, therefore, Walker and the writer (30) repeated the experiments in a slightly different form, exposing suspensions of *Es. coli* to various salt concentrations for half an hour at 37°C. and making both initial and final bacterial counts and ammonia determinations in the menstruum after centrifuging out the cells at the end of the period. The results are presented in Table 5.

TABLE 4

Diffusion Products in Various Menstrua (pH 7.0)

Milligrams ammonia nitrogen per 50 cc.

	ES. COLI		HEAT-KILLED ES. COLI		BACT. CEREUS	
Period of contact, hours	0*	24	0	24	0	24
Distilled water	0.005	0.020	0.002	0.002	0.008	0.090
0.0145 M NaCl	0.007	0.034	0.003	0.012	0.009	0.150
1.450 M NaCl	0.000	0.000	0.000	0.000	0.000	0.000

* Centrifuged immediately after suspension.

TABLE 5

Influence of Salt Upon Viability and Diffusion Expressed as Per Cent of Results in Salt Free Control

	SALT CONCENTRATION			
	0.0	0.05–0.08 M	0.8–0.1 M	2.0 M
Final Bacterial Count	100	110	71	69
Rate of Ammonia Diffusion per Cell per Hour	100	127	84	64

Again it was clear that a dilute stimulating salt concentration increased, while stronger toxic salts decreased, diffusion of metabolic products outward through the cell wall.

It seems then on the whole reasonable to associate the effects of cations upon diffusion products in the menstruum with their influence upon bacterial viability and to conclude, tentatively at least, that dilute salt solutions favor bacterial viability because they increase diffusion processes through the cell wall; and that stronger salt solutions are inhibitive because they

decrease such diffusion processes. Thatcher (34) has classed Na, K, Ca and Mg as "translocation regulators" governing the permeability of the cell. It would seem that other cations subserve the same function.

A recent study by Winslow, Walker and Sutermeister (31) has thrown a little further light on the mechanism of the stimulating process. Most of the work on bacterial viability hitherto discussed has been done by comparing bacterial counts in various salt solutions and in a salt-free control after a definite period of time. Our more recent studies have been conducted by making counts at frequent intervals in a medium continuously aerated with CO_2-free air. When the whole course of the growth cycle is thus followed it appears that both a favorable salt solution (0.1 M NaCl) and a mildly toxic solution (0.5 M NaCl) cause a decrease of bacterial numbers during the lag period of adjustment to a new medium and both show an accelerating effect in the subsequent phase of logarithmic increase. The 0.5 M concentration causes a greater preliminary decrease and a more rapid later increase than the 0.1 M concentration. That the final count reached with 0.5 M concentration is lower than that of the salt-free control is due to the fact that even this rapid logarithmic increase does not balance the earlier decrease. This is the result we might expect if both these concentrations increased diffusion, since a high degree of diffusion, under the conditions of this experiment, would be expected to be unfavorable during the period of initial adjustment (when CO_2 is deficient in the aerated medium) and favorable at a later stage.

CONCLUSIONS

In general, then, it appears that the major effects of salts upon bacterial viability may be explained on the assumption that all cations in low concentration tend to stimulate growth and development while all cations in stronger concentration tend to inhibit growth and ultimately to exert a toxic action. The favorable effect of low concentrations appears to be associated with increased diffusion through the cell wall, the inhibitive action with decreased diffusion.

Individual cations differ very widely in their quantitative influence but, in general, the ratio between the amount of two cations needed to produce any given effect on viability is approximately the same as that between the amount of those same cations required to produce any other given effect. Sodium and potassium are, in general, the least powerful of all cations and the specific potency of other cations may be expressed in terms of the ratio between the molal concentration of sodium necessary to produce a given effect and the concentration of the other cations necessary to produce the same effect. The relative order of the cations with respect to specific potency closely duplicates their position in the E. M. F. series.

The values for specific potency computed in this way range up to 100,000 for such cations as mercury. This wide range in potency does not find its counterpart in any of the more familiar physico-chemical constants of the elements. It is, however, of the same order of magnitude as the effects recorded by Bancroft (32). According to Bancroft's theory, disinfection (like narcosis in the higher forms of life) is due to coagulation of cell colloids, the decreasing stability of these colloids in the initial stages of coagulation being associated with stimulation.

The major effect of anions upon the viability of bacteria appears to be exerted through their influence on hydrogen ion concentration.

Finally, it is by no means contended that

the specific potency of cations and hydrogen ion concentration account for all phenomena of salt action. Studies made in our laboratory have clearly shown that certain electrolytes do exert specific effects which are superposed upon the primary influences of specific potency and hydrogen ion concentration. It seems clear, however, that in studies of bacterial viability, perhaps of other biological phenomena, the possibility of specific potency effects should be taken into account before assuming the existence of salt antagonism or other qualitative salt effects.

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FISHERY BIOLOGY
ITS SCOPE, DEVELOPMENT, AND APPLICATIONS

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FOR a solid sultry week in September, 1908, three hundred official delegates to the Fourth International Fishery Congress which assembled in Washington, D.C., were engaged in the presentation of addresses and technical papers, were taking part in heated discussions and arguments, were dozing through the warm afternoon sessions, or were sightseeing after the usual manner of delegates at such conventions. Fifteen nations were represented, forty-two State Governments and territories, and a dozen learned societies and Government departments sent delegates.

The proceedings, together with the technical papers on a variety of subjects relating to the fisheries of the world, occupy 1400 royal octavo pages in the *Bulletin of the Bureau of Fisheries* for that year. The topics considered ranged from international regulation of the fisheries on the high seas, and the economic and technical conditions of the fisheries in various countries, to plans for promoting fish production in various areas, the life history and habits of aquatic animals, and a litter of papers on the artificial propagation of marine and fresh water fishes and invertebrates. Of course, the inevitable resolutions now having historic interest only were spread upon the record. The contents of the two volume report may be regarded as a fair cross section of intelligent thought upon fishery problems of the time.

Although no meeting of similar scope or aims has been held since that day to provide a record that would show by comparison the progress the world has made in the management of its fishery resources, it is becoming apparent that new concepts of the various branches of fishery science are emerging and are becoming current. At that time fishery technology was an academic term; aquiculture was undefined, and fishery biology, if used at all, had a vastly different content of meaning and implication than it possesses today. Even among men of science these terms are now too often confused, and it is the purpose of this paper to aid in clarifying our concepts of that important field of scientific endeavor variously known as fishery science, or more properly fishery biology.

SCOPE

Possibly fishery science should be interpreted as including all sorts of systematized knowledge regarding the fisheries. Certainly, the biology of the fish upon which the fishery industry depends should be included in this broader definition. Possibly the chemistry and physics of preparation or processing of the fishery harvest for market could properly be included, and even the economics of the fish business, if organized knowledge on this subject exist, could be rated a branch of fishery science; but for practical purposes fishery biology must be much more closely defined. Probably not a few will disagree with me if I limit fishery biology to a relatively narrow field in biological

science, but, on the other hand, many of the views presented below are shared by a growing number of investigators who are becoming class conscious as fishery biologists.

One way of defining our subject is by exclusion. Fishery biology is not ichthyology; it is not statistics of fishery yields, neither is it fish culture, nor fish farming, nor even aquiculture, for the latter may be regarded as a distinct and independent branch of applied science relating to the cultivation of aquatic organisms commensurate in importance with fishery biology. Fishery biology is not identified with stream surveys or the planning of stocking programs. It is neither morphology nor the embryology of fishes. Even the study of the life history or the habits of fishes is distinct from the study of fishery biology and, of course, oceanic biology and limnology are distinct lines of endeavor.

DEFINITION

From this it may appear that there is little left if it be biology at all, but, on the contrary, fishery biology relates to all these, includes elements of many of them, and borrows the technique of others. If a formal definition is necessary, I may offer the following: Fishery biology is that body of organized knowledge regarding the natural supply of fishes commercially exploited, the variations in supply and their causes, and the ways and means of husbanding the fishery resources. It is concerned directly with the commercial fisheries.

I dwell upon the subject of defining the field of our discussion because the aim and purpose of the fishery biologist, his very point of view with regard to his science, is unique and not generally appreciated. Fishery biology must come to be recognized as an independent science, separate from any I have mentioned above, with its own aims and technique. Its relation to zoology is similar to the relation of the various scientific branches of agriculture to botany. Zoology and botany deal with the fundamental biological principles; fishery science and agriculture have certain immediate aims differing widely from those of the parent disciplines, and their techniques must differ in a corresponding degree. Within zoology, the relation of fishery biology is more intimate with ecology, as Russell (1932) has pointed out, and with group biology as developed in population studies and vital statistics than with the classical zoology of individuals—embryology, anatomy, physiology, and taxonomy. Furthermore, in spite of the shock it gives to the conservative zoologist, its relations with economics are very intimate and important.

AIMS AND POINT OF VIEW

Since fishery biology deals with the supplies of fishes and their variations in abundance, the point of view must necessarily be quantitative, for changes in abundance imply measures of magnitude in relation to time. The census of human populations is accomplished by a physical enumeration of the individuals, with which is combined a variety of other facts regarding the characteristics of the individuals that compose the population, but practical difficulties, in the case of the sea fishes at least, make this method entirely impossible for the fishery biologist. Hence, the methods of representative statistics must be employed. A sample of the fish stock is selected with sufficient care to assure its being truly representative of the entire population from which it is drawn. This sample is then studied in detail, and from the characteristics of the sample, the characteristics of the whole may be inferred. A measurement of the accuracy of these inferences involves the theory of

probabilities and all the laws and principles of modern statistical research become at once an important part of the technique of fishery investigations. Someone has said that the maturity of a science may be gauged by the degree to which quantitative observations are employed. Fishery science has passed from the descriptive to the quantitative phase and thus may be rated a mature, if youthful, science.

I have mentioned the practical aims of fishery biology that make it comparable to the science of agriculture. It is therefore an applied science, usually accepted as the antithesis of pure science (but surely the reverse of "pure science" would be "impure science" with which I am unacquainted). Moreover, the final part of my definition, the study of ways and means of effectively husbanding the fishery resources, implies the direction of research activity to the most practical objectives. Fishery biology, therefore, is concerned with useful aquatic animals and the fisheries which they support, and every investigation dealing with other than economic forms falls in some other field of hydrobiology unless it possesses a real and definite relation to the animals that supply man's economic wants.

I do not mean to imply by this that only cod, mackerel, crabs, and the like, should be investigated. I do not intend to exclude a great array of researches upon the natural economy of the ocean or of our inland waters regardless of their complicated techniques and intricate relationships or their circumscribed objectives, so long as each specific project is designed to fill a definite place in our jig saw puzzle of a complete understanding of fish populations. The literature of fishery biology (Allen, 1926) is full of titles representing studies on carefully defined problems, many of which never mention fish, but because of their aim, their intention, their very point of view, fit readily into our growing mosaic picture of the biological background of *fish-as-food*.

The student of biology is doubtless already aware of the existence of a rich and specialized literature on fishery biology in Europe, emanating from the various government departments, the scientific societies, and the biological stations, all of which is well reviewed in various scientific journals and adequately covered by bibliographical services. For the purpose of making more concrete the preceding discussion defining fishery biology and its aims, I may offer a few illustrations of recent research in America which may be regarded as "Simon pure" examples of fishery biology.

No formal treatise has yet been published on the scientific results of a seven year investigation of the biology of the mackerel in western North Atlantic waters, but Fishery Circulars of a popular nature have been published by the U. S. Bureau of Fisheries for the purplose of affording prompt information to the fishing industry. The first of these, "Outlook for the mackerel fishery, 1931" by O. E. Sette (1931), and succeeding circulars under the same title for 1932, 1933, and 1934 not only embody the essential concepts of modern fishery biology, but emphasize the intimate relation between this field of work and economics. The first paper cited reviews briefly the 130 year history of the North Atlantic mackerel fishery in American waters, marked by fluctuations in yield from four million pounds to 120 million pounds annually, mentions the possible causes of these fluctuations and deals at some length with the fact that the immediate cause of such tremendous changes in yield is year-class dominance; that is, the outstanding success of reproduction giving rise to great broods of young in some

years and the virtual failure of reproduction in others. It reviews the size and age composition of the stock of mackerel on which the fishery draws, estimates the mortality from all causes of the various age classes in the stock, and, on the basis of this analysis, forecasts the probable abundance of these same year classes in the following season and the estimated yield for the commercial fishery. In the succeeding papers of the series the same type of analysis and prediction is continued with additional refinements of method based on accumulating experience.

As an example of fishery biology that may well be emulated and as an achievement in research that will rank high in the annals of natural science, the work of the International Fisheries Commission, United States and Canada, under the direction of Dr. William F. Thompson, should be cited. This Commission, appointed under the terms of the convention of 1924 and that of 1930 between the United States and Great Britain for the preservation of the halibut fishery of the North Pacific Ocean, including Bering Sea, has published eight technical reports on its researches since 1930. Its scientific staff has studied where and how the halibut live, the ways in which they are fished, and the effect of this fishing upon the fish supply. Its biological studies have shown the existence of distinct stocks of halibut that inhabit different banks, grow at different rates, and possess different physical characteristics. It has followed from year to year for each stock the intensity of the fishery and the yield therefrom, showing that dangerous depletion had gone unchecked until 1930. From such studies the Commission is in a position to determine in advance the effect of any given intensity of fishing and to devise and enforce regulations of the industry that have already stayed the decline and, indeed, tended to increase the stock.

According to the authors of the eighth report (Thompson and Bell, 1934), "The conclusions from the investigations of the Commission are most striking and of profound importance to the regulation not only of the halibut fishery but, it hopes, also to many other fisheries. They indicate that in each stock the major changes are due to the fishery itself. They show, as might be expected from the history of many other fisheries, that the more intense the fishery the fewer fish survive to a spawning size. They also show that an intense fishery takes the available fish while they are still small, and that a lessened intensity allows them to grow to a larger size, but takes them just the same. Consequently, the ultimate yield obtained by the less as compared to the more intense fishery, from what young do come into the commercial catch, depends upon whether the growth in bulk exceeds or is less than the loss by natural death during the additional period they are allowed to live. Accordingly, where growth is rapid and the weight of living fish increases with time, the great intensity of the fishery is sheer economic waste in that it does not increase the total catch, but actually decreases it, as well as prevents the growth of fish to spawning size. It does not increase the yield, but lessens it, and destroys the supply of spawners. The application to regulation is obvious."

One other recent outstanding contribution to fishery biology in the United States may be cited in "Life History of the Lake Herring (*Leucichthys artedi* Le Sueur) of Lake Huron as revaeled by its Scales, with a Critique of the Scale Method," by John Van Oosten (1929). In this paper Dr. Van Oosten makes a searching inquiry into the validity of the chief method of age determination in fishes, the scale method, and has firmly established its soundness for fishes in general and in particular for the species with which he was

concerned. He then takes up a study of the life history of the lake herring, analyzing representative samples of the population in Saginaw Bay, giving special attention to the age composition of the stock and the rates of growth as affected by commercial fishing operations and other artificial factors in environment, such as pollution of the water. The results in his study of the lake herring in Saginaw Bay plainly indicate a tremendously high mortality resulting from an intensive fishery and remarkable changes in the rate of growth, resulting from chemical pollution during the years 1915–1918.

As an illustration of fishery biology that includes animals other than fish, I may mention "The Relative Growth and Mortality of the Pacific Razor Clam (*Siliqua patula* Dixon) and Their Bearing on the Commercial Fishery," by F. W. Weymouth and H. C. McMillin (1931). After a sufficient analysis of the genus *Siliqua* to establish the fact that the animal under investigation is represented by a single species, *S. patula*, a careful statistical analysis of variability, sexual differences, mortality, and age and growth is made that establishes the growth norms and life expectancy of the populations of this species in different localities throughout its range from Alaska to California. Incidentally, a mathematical expression of the characteristics of growth is derived that may have universal application to all invertebrates and, indeed, to the vertebrates as well. The authors conclude that, with knowledge of the rate of growth, the length of life, and the abundance of young individuals in the different latitudes now available, they can predict the resistance of various clam beds to commerical fishing. Hence, by following a regular system of periodic censuses this valuable resource on the Pacific Coast can be regulated by legal means and permanently protected.

A few other papers may be mentioned. One series in particular bears definite relation one to the other that is not always readily discernible in other similar series: "Fishes of the Gulf of Maine," by Bigelow and Welsh (1925); "Plankton of the Offshore Waters of the Gulf of Maine," by Bigelow (1926); "Physical Oceanography of the Gulf of Maine," by Bigelow (1927); "Seasonal Distribution of Plankton of Woods Hole Region," by Fish (1925); "Production and Distribution of Cod Eggs in Massachusetts Bay in 1924–1925," by Fish (1928); "Statistics of the Catch of Cod off the Eastern Coast of North America to 1926," by Sette (1928); "Fishing Grounds of the Gulf of Maine," by Rich (1930); and "Statistics of the Haddock Fishery in North American Waters," by Needler (1931).

HISTORICAL DEVELOPMENT AND ORGANIZATION

Now that we have sufficiently defined the field of fishery biology a brief review of the historical development of this science will be comparatively easy, for by our definition we have eliminated at a stroke most of the biological research from Aristotle to Agassiz. The publication in 1914 of the noteworthy paper "Fluctuations in the Great Fisheries of Northern Europe," by Johan Hjort (1914), head of the Norwegian Fishery Department, in the *Reports of the International Council for the Exploration of the Sea* may be likened to the ceremonial laying of the corner stone in the edifice of modern fishery biology, and in 1926 Hjort added a few dabs of mortar and gave a little polishing off to the job by publishing his paper, "Fluctuations in the Year Classes of Important Food Fishes" (1926). Although the founding of a science can not be credited to any one man, Hjort probably did more than any other in defining and

giving concrete form to the concept of "vital statistics" applied to fish populations as the central theme of fishery biology. The exploration of the inter-relations of his three major variables affecting the fish supply, "birth rate, death rate, and migrations" and his demonstration of "dominance of year-classes" as causing fluctuations in abundance have had profound effect upon the development of the science and its successful application to practical problems of the fisheries. Of course, as in the construction of a building, work on the foundation and fabrication of the parts had been proceeding for a long time, carried on by many workmen in many places before the bunting was put up and the high-hat notables arrived for the ceremony of cornerstone laying; so with fishery biology foundational studies had been proceeding for perhaps a century before the incident mentioned occurred.

A systematic study of the sea started in earnest about 100 years ago and was carried out at first in connection with the work of survey and exploration undertaken by the naval ships, particularly of Great Britain and of this country. At about the same time zoologists began to extend their interests from the shallow waters to the deep sea by means of the dredge. About 75 years ago the tow-net was introduced as a means of research. Fifty years ago the great *Challenger* expedition was at sea and these researches were followed by the explorations of our own "Albatross," of the German "Meteor," the Danish, "Dana" and the British, "Discovery" (Murray and Hjort, 1912).

During the second half of the last century investigations of the sea fisheries developed gradually in the Scandinavian countries, in Germany, and in Great Britain. In 1871, the U. S. Fish Commission was established to be designated after 1903 as the U. S. Bureau of Fisheries. In the eighties the Fishery Board for Scotland began its notable career and not long afterwards the Marine Biological Association of the United Kindgom began to concern itself with fishery problems on behalf of the British Government. At the beginning of the present century, an important step was taken in the formation of the International Council for the Exploration of the Sea. Its functions were divided between the traditional scientific investigation of the sea in all its aspects, especially the waters bordering northern Europe, and the more modern investigation of the practical problems of the sea fisheries, especially the problems of "overfishing" and "fluctuations."

In America various temporary commissions between the United States and Canada have considered the welfare of international fisheries since 1897 and many of the investigations of the Biological Board of Canada were concerned with fishery problems as early as 1901. In 1921 the North American Council on Fishery Investigations was established and has since been functioning in coördinating researches on the fisheries in the western North Atlantic, and an international convention between the United States and Canada establishing a permament fisheries commission, ratified in 1924 and since renewed, provides for thorough scientific investigation and regulation of the North Pacific halibut fishery.

Thus it may be seen that governments and government supported institutions are the chief agencies for the conduct of fishery investigations. Universities or other private institutions lacking resources and authority for the collection of the basic data seldom undertake direct attacks upon fishery problems, but pursue collateral or fundamental studies.

MAJOR PROBLEMS AND THEIR APPLICATIONS

Doubtless the most significant and fundamental problems of the fisheries are the understanding of the forces and mechanism of "natural" equilibrium and the maintenance of "artificial" equilibrium in fish populations. These major objectives lead at once to (1) the detection of overfishing, (2) the tracing or foretelling of fluctuations in abundance, and (3) the devising of a rational system of managing the supply for the economic advantage of man.

Although many people still believe implicitly in the inexhaustibility of the resources of the sea, in which views they are upheld by contemplation of the vast areas of waters, the tremendous fecundity of aquatic animals, and the antiquity of the great sea fisheries (see McIntosh, 1921), the fear of depletion of the more valuable species by commercial fishing has been the foundation of all governmental activity in connection with fishery investigations. That these fears were not ill-founded is amply proved by experience and, in a few cases, by sound scientific investigation. We need only look back over the statistical records of such fisheries as the Atlantic salmon and halibut, the shad and ale-wife in the coastal rivers of the Middle Atlantic States and in New England, and the sturgeon in these rivers and in the Great Lakes to be convinced that disaster can overtake such fisheries as the inevitable result of intensive or destructive fishing, which in some cases is coupled with the pollution of waters or obstruction of spawning beds (Van Hise and Havemeyer, 1930).

But these, you may argue, are littoral or anadromous fishes. Surely the hordes of fishes that roam the high seas are too extensive to be affected by man's puny influence. It is true that coastal and anadromous fishes being within easy reach of the fishermen's nets or, because of their peculiar life history, actually assembling in mass and coming to the fishermen's very door to be caught are more vulnerable than the pelagic forms. On the other hand even deep sea fisheries are subject to serious reduction as is evidenced by the fate of of the Pacific halibut and by the history of the plaice fisheries of the North Sea.

In the first report of the International Fishery Commission, United States and Canada, W. F. Thompson reported that under the stress of great intensification of fishing effort on the halibut banks from Oregon to the Alaskan peninsula the abundance of fish on the grounds exploited for the longest period had fallen enormously—to 16 per cent of the abundance in earlier years. In 1906, the catch per set of the unit of fishing gear was nearly 300 pounds; in 1926, it was below 50 pounds. Accompanying this fall in abundance there was a decrease in the average size of the fish landed and a great increase in the percentage of undersized fish, all of which indicate the extensive progress of depletion (Babcock, 1931).

It is true that the herring of northern Europe which has supported a great commerical fishery for 1,000 years is still virtually unaffected, the cod in Europe likewise appears to be extremely resistant to fishing, and in the western North Atlantic has produced with only minor variations an average yield of over 100 million pounds annually for half a century. Such species seem to be especially resistant to overfishing.

OVER FISHING

Depletion in the commercial fishery is usually understood as a decline in yield per unit of effort, but a reduced level of supply in any species may be the result of a vast complex of natural causes and not

solely due to overfishing, for great variations in abundance have been observed in nature which are in no way related to depletion.

In the popular mind depletion is too often associated with the record of a declining yield in the market supply. This, however, may not be the case, for the gross figures of landings are affected by too many extraneous influences to serve as more than the merest indication of the true abundance of a species exploited. Thus economic conditions such as a brisk demand and high prices will send more fishermen to sea with more numerous and more efficient nets with the result that even with a constant or a declining supply, total yield will rise, and in a corresponding manner a decreased demand will reduce the yield regardless of the real abundance of the fishes. Hence, the study of over fishing and resulting depletion demands first of all an exact and reliable index of abundance that is uninfluenced by economic forces but measures the population remaining in the sea (Thompson, 1928).

Of course, no attempt is made to determine the absolute number of fishes in any given area, but it is of utmost importance to devise a measure of relative abundance what will be sufficiently accurate to prove whether the stock is increasing or decreasing. For this purpose the yield per hundred hours of trawling with the standard otter trawl has been employed in the North Sea for many years and has yielded valuable results (Russell, 1931). An attempt has been made to derive a measure of abundance from the yield per day's absence from port of the steam trawlers in the North Atlantic offshore banks fishery, but this measure is subject to so many errors that it can scarcely be regarded as suitable. It is, unfortunately, the only measure of abundance that can be applied to the statistics of landings that have been collected in the North Atlantic ports by the Bureau of Fisheries for many years, although more precise records of the actual time spent in fishing are now being collected for a study of abundance of the haddock and mackerel.

The State of California has an admirable statistical system for determining yield per unit of effort from which the yield per vessel per day in the various areas can be determined with great accuracy for tuna, the offshore salmon fishery, and some others. The method of collection and utilization of such records is well described in the paper by Craig (1930).

Overfishing, however, may not be judged alone by an absolute decline in the numerical strength of the fish population in any area, for biological criteria of depletion exist that must be taken into account. It is self-evident that in any intensive fishery in which the strain falls upon mature individuals the relative proportion between the adults and the immature will be materially changed, the adults become less numerous, and the average age of the entire stock decreases. Hence, a decline in the relative numbers of adults combined with a falling yield per unit of effort indicating a decline of abundance, may be interpreted as the beginning of depletion from overfishing, while the occurrence of either phenomenon independently may indicate only natural fluctuations due to variation in reproductive success or a reduced level of abundance from other natural causes.

An analysis of the changing age composition of the fish stock is, of course, dependent upon exact methods of age determination. Probably the first successful method of age determination was that employed by the eminent Danish biologist, C. G. J. Peterson (1892), who published an account of investigations in which the age classes of fish were identified by the tabulation of

their sizes. The frequency of these sizes when plotted graphically showed modes or waves of maximum frequencies about the typical lengths of each age class. This was the length frequency method which is still so much used today because of its convenience of application to large numbers of observations, but because of the fact that the rate of growth of fishes slows down so markedly after reaching maturity this graphical method is limited in its application for individual age classes in the older fish are merged in an indistinguishable mass when their sizes are overtaken by the younger classes.

The length frequency method, although still of wide use for the analysis of size composition, was soon displaced by the more exact and useful method of age determination first developed in 1898 by Hoffbauer, who established the fact that the age of carp could be determined by a microscopic examination of the scales. (See Van Oosten, 1929.) Direct observation and careful experimentation has established the scale method as having universal application to fishes, but because of special circumstances, it is not always practicable with all species. For example, the plaice of the North Sea possess scales that are extremely difficult to interpret and more success has been had in age determination by a study of the structure of the otoliths or ear bones. The same is true of the American halibut (Thompson, 1915), and the scales of the Pacific sardine are illegible.

Throughout the past twenty years, however, the method has been greatly refined. Following Hoffbauer's early announcement, Walter in 1901 discovered that the relative width of a growth zone on a scale was proportional to the growth of the fish in that year. This significant contribution to the method was first studied critically by Lea, in 1910, using the Norwegian herring and from his work we have the familiar scale formula, "Length of scale included in the annulus of year X, divided by the total length of the scale equals the length of fish at the end of year X, divided by the length of fish at the time of capture." Subsequent studies have shown that this is not a constant relation. It was soon criticised by Lee, in 1912, from which we have the "phenomenon of apparent change in growth rate." Gilbert (1913) readily adapted and developed the scale method for the age analysis of the annual spawning runs of Pacific salmon and opened the way for acquiring an understanding and control of the important salmon fisheries of Alaska. Harold Thompson (1929), studying the haddock, has found that the relative growth rate of scales of fish fluctuates from time to time throughout the season. The same phenomenon has been studied many times since and various corrections in the formula have been proposed. R. A. Nesbit of the staff of the Bureau of Fisheries, studying the scales of the weak fish, is making further contributions and refinements in the method at the present time along these lines.

The scale method, therefore, which provides information regarding the age of the fish at time of capture, its rate of growth throughout its life history, and in many cases, as in the Pacific salmon, records of peculiar environments by which distinct races may be identified from peculiarities in scale structure, has come to be one of the most important methods of fishery research and has produced a voluminous literature.

One of the important factors affecting the abundance of fish in any locality is migration which may be periodic and extensive, affecting the entire stock, or casual and local, affecting only portions of the stock. Certain fish such as the

herring can not be considered as uniform in the whole area of their distribution but may be distinguished as local forms or races because they spawn regularly at a certain season or at certain spawning places under definite physical conditions and later commingle in a general feeding area or on the other hand remain segregated throughout life with little or no intermigration. It is a well-known fact that within the same species the isolation of particular stocks of fish tends to develop differences in their physical characteristics or in their physiological reactions. These differences may be entirely the direct result of environment or they may be inherited, but if the stocks are isolated in origin the means and distributions of a series of measureable characteristics differ significantly whereas if intermingling occurs no such average differences remain.

Migrations of fish and the identification of segregated races have been investigated by means of morphometric studies of these local forms. Various structural characters have been used and analyzed statistically such as the counts of the vertebræ, dorsal or anal rays, gill rakers, keeled scales on the herring, and the proportions of the body such as the ratio of head length to standard length and similar proportions. This method has been applied with considerable success in the North Sea and in the Atlantic, to such fishes as the herring, cod, sardine, and other food fishes (International Council, 1929) and the Pacific herring (Rounsefell, 1930). In the last mentioned species Dr. Rounsefell of this bureau has distinguished twelve or thirteen separate races from California to the end of the Alaska peninsula.

Direct methods of tracing migrations include tagging and marking. One of the earliest methods of tagging fish was employed by the Scottish Fishery Board for marking plaice. The identifying mark consisted of two disks of ebonite, bearing serial numbers attached to the fish by a silver wire through the body below the dorsal fin. This tag has been modified many times and is still used today (International Council, 1932). In America a modified form made of celluloid or aluminum bearing complete instructions for return of the tag is being used for cod, haddock, scup, flounders, and croakers on the Atlantic Coast. A metal strap tag of a different form has been used extensively for studying migrations of the cod (Schroeder, 1930) and the Pacific salmon (Gilbert, 1924). Nesbit's new belly tag, a celluloid strip bearing full instructions for return, inserted in the body cavity of the fish, is a startling new development in tagging method that holds great promise.

Aside from the attachment of numbered tags, the most successful method of marking fish is by clipping combinations of fins so that mutilated individuals in different experimental lots can be identified later. This method has been used extensively on the Pacific salmon to mark lots of young fish in the fingerling stage when liberated from hatcheries to trace their migrations and to test the effectiveness of artificial propagation (Rich and Holmes, 1929), and also for marking down stream migrants in nature to provide a mathematical basis for calculating the numbers of progeny from known escapements of spawning fish.

It is a certainty that one of the main factors affecting the quantity and size composition of the stock is the intensity of fishing. Direct evidence of this is afforded in some species by marking experiments. Thus it is definitely known in the plaice of the North Sea that up to 50 per cent or more of the marked fish may be recaptured in a year by fishing vessels. This is generally regarded as an unusually high rate of capture. Figures

cited by Van Oosten (1929), however, indicate that the annual mortality of the lake herring in Saginaw Bay may reach 70 per cent, of which doubtless the greater part is the result of commercial fishing. In the herring of northern Europe indirect methods of calculation have indicated mortality rates in the commercial stock of 20 per cent per annum in the Norwegian spring fishery, and 50 per cent per annum in the East Anglian fishery.

A striking object lesson on the influence of fishing upon the abundance of the stock is provided by the history of the fishery of the North Sea during the War (Borley, 1923). Fishing operations were naturally much restricted during these years and landings of bottom fish fell to less than 30 per cent of the normal amount with the result that the mortality rate due to fishing was materially decreased. During these years more fish survived, stocks were gradually built up, so that when fishing was again eventually resumed landings were considerably higher, and the average size of the fish somewhat greater. The increased yield did not, however, last very long, and the very intensive fishing of the years immediately after the War quickly wiped out this accumulation of stocks with the result that the landings per unit time fell to approximately the pre-war level.

The effects of this partial protection of the stock of plaice in the North Sea during the war period were very thoroughly investigated by the British Ministry of Agriculture and Fisheries, and it was found that by the end of the war the plaice stock had reverted some way towards the state of an unfished or virgin ground. Under such conditions catches are very high, but they consist of large, old fish in rather poor condition, which represent the accumulation of years. As time goes on these old fish are eliminated. The average catch decreases with the average size of the fish, but their quality and their rate of growth is improved and more room is left for the up-growth of new stock. This is precisely what happened in the North Sea during the war and serves to emphasize the extreme complexity of the problem of overfishing. Parallel conditions exist in the Pacific halibut fishery as mentioned above.

Commercial interests in this country have advanced the proposal that overfishing need not be investigated, and that any regulation whatever of the intensity of fishing by governmental means is unnecessary on the grounds that the level of abundance of the fish supply will fall to a certain point known as the "least economic level," beyond which it would be unprofitable to exploit the fishery by any but the most efficient business units, and that the strain of fishing will thereby be relieved (Taylor, 1930). This is doubtless true, but we have no assurance that the least economic level will be the most productive one in food for the nation. Obviously, that level of abundance should be maintained that will induce maximum growth and replacement coincident with the greatest withdrawals from the supply that can be taken year by year without jeopardizing future production.

Since it is impossible to predict in advance the strain of fishing that any stock can withstand without permanent impairment, the study of overfishing is reduced to a routine of continuous observation in which the trend of the supply and the composition of the stock are given proper attention and analysis.

FLUCTUATIONS AND PREDICTIONS

The expression "fishermen's luck" summarizes the fact that the yield of the fisheries both locally and over wide areas is extremely erratic and a great mass of

scientific evidence now available indicates that these changes in yield are primarily due to major fluctuations in the actual abundance of the various fish stocks. These variations in abundance are also found in land animals, and attempts have been made to discover cyclic variations related to world-wide factors such as solar variations and the like. The problem has a very practical bearing. In certain communities, in northern Norway, for example, where the population is mainly dependent upon the fisheries for a livelihood, the success or failure of the fishing is, or used to be, a matter of life and death.

"It is natural therefore," says Dr. Russell (1932, p. 136), "that the study of fluctuations was tackled first and most energetically in Norway under .... the direction of Dr. Johan Hjort, then director of fisheries..... It happened fortunately that at the time Hjort's work started (in 1901) the technique of age determination in fish by means of scales and otoliths was just being worked out. This method was applied with great success to the study of the herring, and it soon became established that the main cause of the fluctuations in the great spring herring fishery was the success or failure of the individual broods or year-classes composing the stock. Thus it was found that the 1904 year-class was remarkably abundant, and it predominated in the catches for many years, providing a rich fishery. It still persisted, though in greatly reduced numbers, for some years after the war, and meanwhile the stock was replenished by other good year-classes such as those of 1913 and 1918; intermediate year-classes were very poor.

"Similar methods applied to the Norwegian cod, supplemented by extensive measurements, demonstrated the existence of especially prolific brood-years, as for example those of 1904 and 1912, while other years contributed little to the stock.

"The same general method of determining the age-composition of the stock, and particularly the abundance of the incoming year classes or recruit-stock, has been used with success also on the North Sea, particularly by Dr. Harold Thompson for the haddock and by Dr. Hodgson for the East Anglian herring fishery."

Indeed, the problem of large scale fluctuations ever since the publication of Hjort's paper of 1914 has received much attention from fishery investigators in Europe and has been actively studied as shown by the papers of twenty authors, published by the International Council (1930), under the title, "Fluctuations in the Abundance of the Various Year Classes of Food Fishes."

In America the study of these fluctuations in abundance forms the major activities of the research staff of the Bureau of Fisheries in the North Atlantic area and is being applied to the haddock, mackerel, scup, and weakfish. There can be no doubt that this general principle applies to the supply of all fishes, but probably the most spectacular variations in abundance are found in the mackerel fishery which has been studied for several years by O. E. Sette of the Bureau of Fisheries (*vide ante*).

From a study of the age-composition of the commercial catch of mackerel, together with the records of landings, data have been secured which indicate that the year-class produced in 1923 was extremely abundant. Probably the next in order of abundance was the year-class produced in 1928. The 1929 and 1930 year-classes were relatively less important and reproduction in all of the other years since 1923 was a virtual failure. So abundant, indeed, was the 1923 year-class that it largely dominated the fishery up to and including 1932, the most recent year for which an analysis is complete.

On the basis of these studies in which the relative strength of the various year-classes is calculated, together with their rates of decline, predictions of the expected yield have been offered for several years. These predictions have great potential value to the fishing industry. If a season of unusual abundance may be foreseen, marketing channels may be prepared for expanding distribution, and the technological processes such as freezing,

salting, canning, and packing may be planned to take care of the excess production, thus reducing glutted and demoralized markets, which too often drive prices so low as to cause real distress among the fishermen. Conversely, in seasons when scarcity appears inevitable, the cost of such preparations can be saved and accumulated stores of processed fish may be released to supplement current production.

Although no reports have been published, similar predictions have been prepared for several years for the major runs of salmon in the important fishing districts of Alaska. Strangely enough these predictions are based on less precise data than are available for the pelagic sea fisheries. They include such factors as the known escapement of spawning salmon and their age-composition, the physical conditions upon the spawning beds, the estimated production of young salmon migrating seaward, the normal age at maturity, and various other indications such as, for example, in the red salmon, the number of grilse or precocious males returning in the year previous to the year of prediction, which is believed to bear a fairly definite relation to the number of normally maturing adults. These predictions are becoming increasingly accurate and already have provided such valuable information that they are accepted as an important basis for the regulation of the fisheries by the Government and for the commercial preparations for packing activities the ensuing year. There is no doubt that additional research along these lines will bring still closer the practical control of fishing operations and the maintenance of the stock of fish.

Little is known so far about the causes of these fluctuations in the great fisheries. One thing appears reasonably certain: that there is no necessary correlation in the case of pelagic fishes between the numbers of eggs produced in a particular spawning season and the number of fry which survive. On the contrary, good brood years have often been poor spawning years. The fate of the year-class is probably settled at a somewhat later stage, possibly in the larval or post-larval stage. Various factors have been adduced as probably affecting survival—lack of planktonic food for the newly hatched larvae, variation in temperature, variation in normal courses of currents drifting the larvae to localities unsuited to their growth and development. Much work still remains to be done before this complex problem can be solved and here is introduced to the field of fishery biology the great range of studies included in oceanography and limnology, the embryology and physiology of development, etc., that may have been regarded as basic or foundational studies or, indeed, only remotely related to fishery biology. Clearly the problem is an ecological one and nothing short of a full knowledge of conditions of existence of the species concerned, of its relations to other forms of life, of its food and competitors, will suffice to solve it.

FISHERY MANAGEMENT

Space will permit but a few remarks on the subject of protecting or wisely using the fish supply even though this subject represents the cutting edge of the tool of which the more technical phases of fishery biology are the handle. Certainly, the application of our knowledge of the status and trend of fishery resources, their natural fluctuations in abundance, and the life history and habits of the fishes they represent, must be applied in maintaining and utilizing the wealth of the waters. Doubtless, it is because of the youthfulness of fishery biology itself that the methodology of fishery conservation is so little

developed. The protection of the fisheries even where depletion is clearly evident is still very largely a matter of trial and error with uniformly too little effort applied to observing or correcting the "error." It is in this field that the fishery biologist is most directly confronted with problems in economics, for the protection of a fish supply is accomplished by the regulation of the business enterprise of fishing which in turn affects a series of related industries.

As pointed out by Thompson (1919) the application of corrective or preventive measures for the protection of a species threatened with depletion is dependent upon the nature of the species to be protected. One of the important considerations in this connection is the extent of migration which occurs, for if the species ranges over a wide territory regulatory measures must be applied over the entire range. On the other hand, if a species is largely localized, or is composed of segregated populations or races, protective measures may be applied only to those areas where the fishery is prosecuted most intensively, or, in case depletion is more general, closed areas may be established and alternated after a period of years with the areas in which fishing is permitted so as to provide a rotation that will favor natural recuperation of the species during the seasons of closure.

Conservation authorities are continually confronted with demands to prohibit fishing particularly in inshore waters during spawning seasons, to prohibit the capture and sale of immature sizes, to regulate or prohibit the use of efficient and, therefore, "destructive" types of fishing gear, or to close certain areas to commercial fishing. Many of these demands are certainly based upon economic reasons rather than biological, for in general fishing during the spawning season is no more destructive to the species than at any other time of the year, barring the increased expectancy of survival until spawning as hazards of life are passed.

This is a subject on which there is very general popular misunderstanding. Arguing from the familiar domestic animals and game, it is generally believed that breeding individuals are somehow particularly vulnerable and therefore should be given special protection. Since the survival of any species depends upon the production and survival of a sufficient number of eggs, it is important to determine, as pointed out by Herrick (1911), "the life rate or law of survival," which is a measure of the hazards which must be survived by the progeny of each pair of adult individuals. The reproductive capacity of any individual is measured by the total number of eggs produced in the average life time, and the destruction of these eggs is equally as serious in the case of catching an immature fish in its early stages of development as it is just prior to actual spawning. The worth of an individual to the species for the purpose of reproduction, however, as measured by the life rate or expectancy of survival increases as the spawning period approaches and as the dangers of destruction are surmounted. As Thompson (*loc. cit.*) says, "The question is simply one of where it is best to take toll of the supply, considering first the survival of the species and then the age or time at which the available surplus may best be taken. Is it best to take the immature before the natural perils of the sea have reduced their numbers or to take the mature after they have increased greatly in average size? . . . In other words, which has the least value to the species weight for weight?" Of course, certain species that school densely for spawning are more readily taken at that time. Fish taken at the spawning time or immediately after are

inferior in quality as a food product and, in species for which there is an active demand for roe, spent fish have naturally a reduced value and hence their protection at that time is based on economic considerations.

There are economic reasons also for preventing the sale of small fish for they usually bring lower prices, although the same frequently applies to the largest specimens as well. Closed seasons at various times of the year other than the spawning period are frequently demanded in order to prevent the taking of an oversupply that will demoralize markets and reduce profits, and closed areas are frequently designed to prevent the taking of large quantities of small fish having little market value. Because these demands are economic rather than biological, they are often frowned upon by professional conservationists, but, as in the utilization of any other food animal, the principle should apply to the fisheries that the individuals of a species should not be taken until they have passed the period of maximum growth, and until they have reproduced a sufficient number of times to maintain the species. They should be taken at the time when they have the highest market value and the greatest food value. Even this principle is not always applicable, for some species such as the shrimp of the South Atlantic States are utilized chiefly when immature.

With these principles in mind we may again consider the protection of undersized fish. Most of these if spared would grow to marketable size. Common sense indicates that such protection would increase the yield of marketable fish, but the problem is not so simple as it seems, for the question of degree comes in. Possibly thinning out the stock at a very early age might be very advantageous while thinning later on might be disastrous depending, of course, upon the period in the life history of the fish during which greatest natural mortality occurs. The problem is to some extent susceptible to exact mathematical treatment if we know certain fundamental food ratios, namely, the amount of food relative to body weight required to keep weight constant, and secondly the relation between growth in weight and the amount of food required to produce this growth. Experimental studies on this subject have been carried out at the Plymouth Laboratory in England (Dawes, 1930, 1931), but little investigation of this type has been conducted in America.

The question of the adequacy of the food supply has been studied in Europe by Peterson (1918) and others, but in America it has been assumed generally that the food supply is normally super-abundant for the existing fish population, and on this basis the Bureau of Fisheries has been devising commercial gear that will permit the escape of a large proportion of undersized fish from the trawl catches of haddock in the North Atlantic and from the pound net and gill net fishery in the Great Lakes (Higgins, 1933). We have no assurance, however, that such measures will be adequate to stay the threatened decline in these fisheries.

In Alaska the protection for the salmon runs has been effectively provided by limitation upon the commercial catch. The number of salmon traps is limited indirectly by locality restrictions, and the fishing period for all types of gear is restricted to but a portion of each week. In this way at least one half of the total run of salmon is permitted to escape the fishing gear and enter the rivers for spawning. Recent observations, however, indicate that a far better means of conservation would be to require by law the escapement of a definite number of salmon, adjusted

according to the capacity of available spawning grounds rather than to protect a fixed percentage of the total run.

Protection of the halibut fishery of the North Pacific through authority of the international treaty is provided by an arbitrary limitation of the quantity of halibut that shall be landed from the various areas into which the fishing grounds are divided for statistical purposes. Quotas are assigned to each of these areas that may not be exceeded by the fishing fleet and when that yield is attained all fishing ceases for the year. Through careful study of the effects of such limitations by the fishery commission and through the enforcement of proper regulations, the decline in abundance can certainly be stemmed although, because of the slow growth of the species, many years will be required before recovery of the stock will be apparent.

Experience is too limited to permit the expression of general principles or laws universally applicable to fishery conservation. In general, however, it is admitted that, since the depletion of stocks is almost uniformly the result of overfishing, the remedy lies in reducing the strain of exploitation. How this may best be accomplished depends upon a variety of local circumstances which the fishery biologist must take into account even though they frequently lie outside of the conventional field of biological investigation.

In the foregoing pages, I have cited the views of many workers and referred to the more recent literature in an attempt to define the boundaries of the current and the central drift of fishery science in the sea of marine biology.

It may be seen from the evidence here presented that fishery biology no longer includes the diffuse and nebulous aims of the older students of natural history in which every fact concerning fish and their environment is regarded as having equal importance and being equally worthy of study. If another international fishery conference were to be held at present no such general program as that of 1908 would be arranged. Different sections would doubtless be organized including separate discussions of fishery technology, aquiculture, and fishery biology at least. Investigators of fishery problems may not have narrowed their interests, but they have defined more clearly than ever before their objectives and have concentrated their efforts upon the more immediate and practical demands of industry to define and recognize overfishing and to manage rationally the fish supply for the permanent good of humanity.

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PROPERTIES OF WATER OF BIOLOGICAL INTEREST

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INTRODUCTION

THE peculiar fitness of water as a medium for life is a subject which has received much attention for a number of years (Henderson, 1914, 1927; Bayliss, 1927). If one were to describe, on theoretical grounds, the supposed properties of the substance H_2O, these properties would differ widely from those of the substance we know as water. The boiling point, for instance, should theoretically be −100°C. and the melting point −150°C. (Duclaux, 1912, p. 882); however, these values for water are respectively 200° and 150° higher than the theoretical ones. Other peculiar properties of water are its anomalous variations in specific heat, its high heats of fusion and vaporization, its maximum density at 4°C., its anomalous thermal expansion, its minimum of compressibility at 50°C., its high surface tension, and its changes in magnetization constant. All of these abnormalities can be explained only on the supposition that water is highly polymerized (i.e., composed of H_2O, $2H_2O$, and $3H_2O$, etc.) and that the ratio of these polymers changes with change of temperature or that the molecules are arranged in a complex which changes with temperature. For example, the maximum density at 4°C. can be explained by the association theory, for, superimposed on the normal thermal expansion curve is a contraction curve due to the conversion of bulky ice (trihydrol) molecules into the denser dihydrol molecules, the effect of the two processes on the total volume being equal and opposite at 4°C. Concerning this effect Tyndall (1889, p. 120) wrote "this halt [in contraction] of the approaching molecules at the temperature of 39° [F.] is but a preparation for the subsequent act of crystallisation."

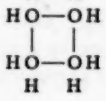
In previous papers (T. C. Barnes, 1932; H. T. Barnes and T. C. Barnes, 1932; Lloyd and T. C. Barnes, 1932) it was reported that filaments of *Spirogyra*, especially *S. nitida*, would live longer in water which had recently been ice than in water which had recently been condensed from steam (water changed daily in both cases). The working hypothesis was suggested that the polymerized molecules (trihydrol) were factors conditioning the observed difference. However, in *Spirogyra* neither the general appearance of the cells nor the extent of the mass of filaments permits quantitative studies. We have performed similar experiments with a protozoan, *Euglena gracilis*, in which it is possible to determine the number of individuals per ml. of water (T. C. Barnes and Jahn, 1933).

No extensive review of the association of water has appeared for twenty-three years (*Trans. Far. Soc.*, vol. 6, 1910, p. 85) and it seems desirable that a review of the more important phases of this subject be made available to biologists. The present paper gives a review of the association of water and its isotopic composition, particularly from the viewpoint of the general physiologist, together with certain data on the effect of ice water on *Euglena*, and further data on the rate of freezing of ice water and steam water. The rather oner-

ous "library work" was found necessary in connection with replies to numerous and stimulating criticisms of the trihydrol hypothesis in biology (cf. T. C. Barnes, 1934b).

EARLY WORK

The best short résumés of the association of water are those of Duclaux (1912), Turner (1915), Mellor (1922, pp. 411–421), Friend (1924), Chadwell (1927), H. T. Barnes (1928) (Bibliography), Longinescu (1929) and Honigmann (1932). It is not generally known that Whiting (1884, p. 71) was the first to develop a theory postulating the presence of dissolved ice particles in liquid water at all temperatures. Whiting believed that in freezing water there might be somewhere between 25 and 38 per cent dissolved ice, and in boiling water somewhere between 17 and 23 per cent. He also believed that the true expansion of water (apart from the contraction caused by the melting of dissolved ice) between 0°C. and 100°C. was not only 4 per cent but probably 8 to 10 per cent. In the same year Raoult from a consideration of the freezing point of solutions pictured the water molecules in groups of four which he later (Raoult, 1895) considered to be groups of twos. Vernon (1891) explained the temperature of maximum density of water by postulating that the water molecules aggregate together and form more complex molecules than before existed. The density begins to decrease when about half of the molecules have undergone aggregation. Water from 100° to 4° has the formula $(H_2O)_2$ and below 4° these molecules will condense to $(H_2O)_4$ molecules which Vernon pictures as:



Röntgen (1892), in a paper which Sutherland describes as "elegant but brief," independently proposed that water contains dissolved ice particles, and he used this hypothesis to explain several of the unique properties of water. On this assumption the decrease in the compressibility of water from 0° to 50°C. is due to the smaller percentage of bulkier ice molecules as the temperature is increased. Röntgen also refers to Amagat's demonstration that the expansion coefficient of water between 0° and 10°C., 0° and 30°C., and 0° and 50°C. increases with pressure up to 2500–3000 atmospheres and is greater at lower temperatures. This is in contrast to simpler liquids such as ether and alcohol whose coefficient of expansion decreases with pressure. Röntgen's third point is that the viscosity of water can be decreased by pressure, while that of most simple liquids is increased under pressure. Pressure dissociates the viscous trihydrol which may more than compensate for the usual increase of viscosity with pressure. The two effects are equal at about 30°C. (cf. H. T. Barnes, 1928, p. 40). The phenomena can be explained on the assumption "dass flüssige Wasser aus einem Aggregat von zwei Arten verschieden constituirter Molecule besteht."

Van Laar (1899) in a mathematical paper on the association of water and of alcohol considered fluid water as a system of single and double molecules (Table 1) and explained the contraction of alcohol-water mixtures as a dissociation effect (but cf. Bancroft and Gould, 1934).

Probably the most extensive and at the same time the most speculative paper is that of Sutherland (1900), who calculated the percentage of trihydrol at various temperatures. It must be remembered that Sutherland held to the binary theory of the association of water, postulating that the liquid form is composed of trihy-

drol and dihydrol only. Later work, however (Callendar, 1902; Bousfield and Lowry, 1905; Rao, 1934), indicates that water is a ternary system containing hydrol or steam molecules, at least in the range of 60° to 100°C. Southerland calculates the densities and properties of his two ingredients on the assumption that each constituent follows Mendeleeff's law of expansion of liquids between 0°C. and their boiling points, that is,

$$\rho = \rho_0 (1 - kt)$$

or that the density (ρ) is a linear function of the temperature. Expressed graphically, with t as abscissa and ρ as ordinate, the equation gives a straight line for ordinary liquids, but the corresponding graph for water is a curve with a maximum density indicated at about 4°C. At higher temperatures Sutherland's curve approaches asymptotically the straight line for a simple liquid. Therefore he assumes that the asymptote represents the behavior of one of the pure ingredients of water (di-

TABLE 1

Percentage of Trihydrol at Different Temperatures According to Various Authors

Whiting (1884), p. 71.

STATE OF WATER	MELTING ICE	FREEZING WATER	AT 100°C.
% "solid particles"	About 50–70	About 25–35	About 17–23

van Laar (1899), p. 6.

Temp. °C.	20°	100°
Fraction of "Double Molecules"	4/5	3/5

Sutherland (1900), p. 464.

These values give a smooth curve when plotted against the temperature shift in the infra-red bands of Plyler at 1 and 1.2μ (Cf. H. T. Barnes, 1928, p. 85).

Temp. °C.	0°	20°	40°	60°	80°	100°	120°	140°	198°
% Liquid Ice	37.5	32.1	28.4	25.5	23.4	21.7	20.3	19.1	16.5

Duclaux (1912).

Temp. °C.	0°	100°
Grams of ice per liter of water	200–300	50

Richards and Chadwell (1925), p. 2293.

Temp. °C.	0°	20°
% "polyhydrol"	39	28

Tammann (1926).

Temp. °C.	0°	10°	20°	30°	40°
Proportion of molecules of Ice I per gram of water	0.15	0.12	0.08	0.06	0.04

Rao (1933).

SUBSTANCE	ICE	WATER AT 0°	WATER AT 4°	WATER AT 38°	WATER AT 98°
% H_2O	0	19	20	29	36
% $(H_2O)_2$	41	58	59	50	51
% $(H_2O)_3$	59	23	21	21	13

hydrol). By analysis of the curve he finds that water at 0°C. consists of 37.5 per cent liquid $(H_2O)_3$; density 0.88, and 62.5 per cent liquid $(H_2O)_2$, density 1.09 (*vide* Table 1). The latent heat of fusion of trihydrol, 16 calories, is calculated on the assumption that it would expand 0.0366 on fusing, 0.0366 being the mean expansion of a number of metals. The average expansion on melting of solids such as Pb, Cd, Sn, Na, K, P, and Hg (data of Vincentini) is 3.3 per cent, while in the case of water there is a contraction of 8.3 per cent. This difference led Sutherland to believe that "the solidifying of water into ice is no mere physical change of state, as with most melting bodies, but is chiefly a profound chemical change." The remainder of the latent heat of fusion of ice is supposed to be made up of the *heat of dissociation* of 62.5 per cent of the ice into dihydrol and the heat of solution of the remaining fraction (37.5 per cent) in dihydrol.

Sutherland supports these conclusions by appealing to the then existing data on optical refraction, compressibility, surface tension, specific heat, viscosity, and dielectric capacity, all of which, with the possible exception of the last, appear to vary with temperature according to Sutherland's scheme of the changing proportions of ingredients.

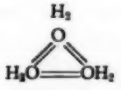
From the standpoint of general physiology Sutherland's speculations concerning the surface tension are of extraordinary interest. According to Eötvös, if Mv is the molecular volume, α the surface tension, and $\alpha(Mv)^{2/3}$ the molecular surface energy, σ, then $d\sigma/dt$ is nearly the same for all normal liquids and remains almost constant (2.12) until the critical temperature is closely approached. For associated liquids of varying degrees of association, $d\sigma/dt$ is not constant and is of a lower value than for unassociated liquids. Since this value for water ($M = 18$) near 0°C. is about 0.92 (data of Ramsay) and rises with temperature, it is assumed that water is associated and that an increase in temperature results in a decrease in the amount of association. In order to bring the value of Eötvös' constant nearer to 2.12, it is necessary to multiply by $3^{2/3}$, thereby assuming that the surface layer is $3H_2O$ or that it has an average molecular weight of 3×18. This gives 1.91, and a further correction for density necessitates multiplying by $(1/0.88)^{2/3}$, where 0.88 is the derived density of trihydrol (*vide supra*). This factor raises 1.91 to 2.08, a figure near enough to 2.12 to suggest that the surface film of water at about 0°C. consists *entirely of trihydrol*. Thus it appears that the tension in the surface layer of water at 0°C. is sufficient to cause nearly all of the water there to change into trihydrol, the surface tension of which is that of water at 0°C., namely, 73.32 dynes per cm. This appears logical enough, for if compression dissociates, tension might be expected to associate the water molecules. By Eötvös' relation the surface tension of trihydrol at any temperature is given by the equation:

$$\alpha_3 (54/\rho_3)^{2/3} = 73.3\,(54/.88)^{2/3} - 2.12\,t$$

Sutherland's calculations indicate that up to 40°C. the surface film of water consists of pure trihydrol, but that at 60°C. and higher temperatures the surface tension is so much reduced as to allow some of the lower polymers to form. However, in this connection we must remember Nernst's (1923, p. 322) suggestion that although deviation from the constant of Eötvös indicates association of a liquid, it is impossible to conclude satisfactorily the *precise degree of association*. Shereshefsky's (1931) recent modification of the Eötvös equation has not yet been applied to associated liquids. Adam (1930, pp.

153–155) discusses the value of Eötvös' law and considers cases where it cannot be applied.

Sutherland also suggests that the empirically well known properties of surface tension of aqueous solutions must be due largely to the difference between the surface layer and the body of the water and to the dissociation of some of the trihydrol by solutes. This was demonstrated later by Bousfield and Lowry (1910). Sutherland points out that the solubility of substances in trihydrol may be different from that in dihydrol and that a re-examination of surface tension of solutions from this viewpoint would be of great interest. Finally, he proposes a following structural formula for trihydrol:



The physical constants of Sutherland's polymers are given in table 2.

TABLE 2

Physical Constants of Water Polymers. (*Sutherland, 1900*)

CONSTANT	DIHYDROL	TRIHYDROL
Density ρ at 0°C	1.08942	0.88
Temp. coeff. of density, k	0.0009	0.0002
Compressibility per atmo. at 0°C	0.000016	0.000010?
Surface tension at 0°C	78.3	73.32
Critical temperature	368 C.	538 C.
Specific heat at 0°C	0.8	0.6
Latent heat of fusion		16 cal.
Latent heat of evap. at 100°C	257	250 (near)
Viscosity at 0°C	0.0030	0.0381
Pressure-coeff. of viscosity per atmo		0.00034

$2H_2O = (H_2O)_2 + 189 \times 2 \times 18$ cal. $3(H_2O)_2 = 2(H_2O)_3 + 177 \times 6 \times 18$ cal.

Addenda:

Rate of dissociation of one gram of trihydrol by pressure (grams per atmo.) at 0°C., 0.00017; at 100°C., 0.0001

Recession of temperature of maximum density with pressure = 0.025°C. per atmo. (Amagat)

SPECIFIC HEAT

The existence of dissolved polymers in liquid water is briefly considered by Callendar (1902) and H. T. Barnes (1902) in their studies of the variation in specific heat of water with temperature (Table 3). Callendar (1902) was quite critical of Sutherland's interpretation of the specific heat of water. Sutherland, assuming the usual rate of increase of specific heat of a liquid (0.1 per cent per degree), calculated the specific heat of pure dihydrol and of pure trihydrol to be 0.83 and 0.6, respectively, at 0°C. He explained the remainder of the specific heat of water as being due to the heat of dissociation of part of the dissolved trihydrol and the heat of solution of the dihydrol thus formed. Callendar put forward the suggestion that the high specific heat of water may be due to "internal work done against molecular forces, and as being closely related to the decrease of latent heat of vaporization with rise of temperature." Further details of this line of argument may be obtained from the original paper (pp. 146–148). Callendar, however, was the first to postulate the existence of steam molecules in liquid water, and since his time the ternary theory of the constitution of water has been widely accepted. Water,

according to this theory, is composed of monohydrol, dihydrol, and trihydrol, and the ratio of these substances varies with the temperature. The amount of trihydrol decreases as the temperature is raised above the freezing point, and the amount of monohydrol decreases as the temperature is lowered from the boiling point. In this way Callendar explains the increase of specific heat as the freezing and boiling points are approached; this theory also accounts for the anomalous expansion. Recent papers by Callendar (1929) deal with the properties of steam at great pressures and at temperatures far above the biological range.

TABLE 3

Variation of the Specific Heat of Water (selected values from the curve of H. T. Barnes, 1902, p. 252) to Show the Minimum

TEMP.	SPECIFIC HEAT
5°	1.00530
15°	1.00030
25°	0.99806
35°	0.99735
45°	0.99760
55°	0.99850
70°	1.00035
85°	1.00237
95°	1.00370

The specific heat curve of H. T. Barnes (selected data in Table 3) shows a well marked minimum at 37.5°C. As we shall see later, other properties of water such as solution volume with certain salts have a critical temperature at this point. A possibly significant coincidence which has not been pointed out previously is that this is a typical mammalian body temperature. A rise in specific heat with rise in temperature (similar to that which occurs in water above 37.5°C.) is a general phenomenon in normal liquids, but the rise in specific heat of water as the temperature is reduced below 37.5°C. is an abnormality which H. T. Barnes suggests might be due to the interesting possibility "that water commences to anticipate the solid phase, even before 0° is reached."

In the same paper H. T. Barnes gives an interesting quotation from Rowland's (1879) early work on the specific heat of water. Rowland points out that the decrease of specific heat with rise of temperature is no more remarkable than the contraction to 4° and "in both cases the water hardly seems to have recovered from freezing" (p. 131). This is, in all probability, the first suggestion which could be interpreted as indicating the presence of trihydrol in water, although Rowland unfortunately is not clear concerning his identification of latent heat and specific heat. Henry (1905) points out that water is formed from two perfect gases, one H boiling at −253° and the other O at −184° which unite to form a liquid boiling at 100° which indicates polymerization. According to Longinescu (1929), Henry was the first to propose the general theory of association in liquids.

Hudson (1905) explained the constant temperature of freezing by assuming that the ice molecules have a definite solubility in water as well as a definite equilibrium concentration varying with temperature. A second substance decreases the amount of ice molecules, making it necessary to cool the solution before equilibrium concentration reaches the saturation point of the ice molecules.

SOLUTION VOLUME

Bousfield and Lowry (1904) made a careful study of the solution volumes (defined below) of NaOH with special reference to the effect of solute upon the water polymers. Their data support the ternary theory of water, and this interpretation is further supported by later experiments on the solution volume of several important salts and other substances (Bousfield and Lowry, 1910). Although not many, these range from the slightly hydrated chloral hydrate through $AgNO_3$, cane sugar, acetic acid, the physiologically important salts KCl, NaCl, and $CaCl_2$, to the strongly hydrated LiCl. The actual solution volumes of the physiological salts are much smaller than those of the organic compounds—only 0.24 to 0.35 cc./gm., but variations are much greater. The

curves for KCl and NaCl show a maximum solution volume at about 60°C., which is most pronounced in dilute solutions. The solution volumes of KCl are larger than those of NaCl, the solution volume of a 2 per cent KCl solution being larger than that of 10 per cent NaCl. The curves for $CaCl_2$ and LiCl are most abnormal and show maxima at 50° and 35°C., and these are more pronounced in 40 per cent than in 10 per cent solutions. This work is of special interest in general physiology, for the dissolved substances in organisms undoubtedly have a pronounced effect on the state of water in the tissues. Bancroft and Gould (1934) have recently explained the Hofmeister series of anions on the basis of the specific effect on water polymers. Also, the effect of salt on the water polymers determines in part the physical constants of sea water (*e.g.*, absence of maximum density).

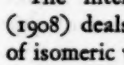
The method used by Bousfield and Lowry is essentially a comparison of the properties of water with those of a graded series of aqueous solutions of which water may be considered as a limiting member. The initial experiments with NaOH revealed that water is the most complex of the series, and that as the concentration of solute is increased the behavior of the liquid becomes increasingly simple. Thus the maximum in the density-temperature curve of water disappeared on the addition of 2 per cent NaOH; from 12 per cent up the relation is expressed by a simple parabola, and at 42.5 per cent the relationship between density and temperature becomes strictly linear from 0° to 100°C. These curves showed further that the abnormal properties of water were not confined to the vicinity of the freezing point. A second region of abnormality, not previously recognized, appeared in the neighborhood of 60°C., and developed with increasing magnitude as the boiling point was approached. This was due to the production of steam molecules of simpler composition than typical water molecules but which, like Röntgen's ice molecules, possessed a greater specific volume. Increase of specific heat with temperature is a general phenomenon of normal liquids, and therefore previously observed increases in specific heat of water might have been explained by causes other than further dissociation, but the solution volume data of Bousfield and Lowry seem to be open to no other interpretation. These data are, however, easily explained on the basis of the ternary theory.

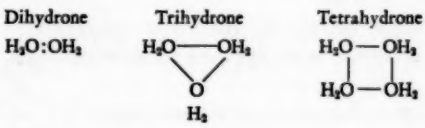
Bousfield and Lowry believe that their evidence for the ternary theory is much safer than that obtained by earlier workers with other methods. The term "solution volume" indicates the increase in the volume of the liquid which takes place when 1 gram of the solute is dissolved in a given volume of the solvent. Thus 1 gram of NaCl dissolved in 100 cc. of water increases the volume of the liquid to 100.2 cc., and the solution volume of the salt is 0.2 cc. per gram. A normal solution volume is the real volume of the solute in the liquid state diminished by any contraction which takes place on solution. Solution volumes vary with temperature and with the concentration of solute, and under certain conditions may be zero or even negative. For instance, it is possible to dissolve 140 gms. of NaOH in a liter of water at 0°C. or 100 gms. in a liter of water at 100°C. without increasing the volume of the liquid. In a simple liquid the thermal expansion proceeds in such a way that the rate of increase in solution volume becomes progressively greater as the temperature rises, so that normal solution volume-temperature curves should be of the same general character. A constant contraction (from the formation of hydrates) would affect only the *position*

and not the *form* of the curve. Therefore, the striking distortions actually observed must be attributed to variations other than the formation of hydrates. The simpler behavior of concentrated solutions indicates that the distortion of the solution volume curves must be attributed to the changing character of the water rather than to alterations in the hydration of the solute. These distortions are easily explained on the basis of the changing character of the water with temperature.

The fact that a contraction in total volume usually accompanies dissolution of a salt capable of hydration shows that water combined as hydrate has a greater density than the same water before it was combined. Contraction would result from the conversion of the bulkier types of molecule ("ice" or "steam") into the more dense ones of the hydrate. The density of combined water may be taken as 1.1 (KCl), which figure may be compared with 1.089 given by Sutherland for dihydrol. Contraction is maximum when the solvent is present in large excess, and variations in solution volume with temperature are largest in dilute solutions. If we compare solution volume curves of various solutes in the order of their affinity for water, the curves change from concave (chloral hydrate) to convex (acetic acid) and finally show a maximum (LiCl), and as the solutes have a greater and greater affinity for water, the maximum of contraction shifts to lower and lower temperatures. The lowest given minimum temperature for the maximum contraction is that of LiCl at 35°C., and it is interesting to note that this is close to the minimum in the specific heat curve (37.5°C.). Any further lowering of the temperature of maximum contraction would be rendered impossible by the increasing proportion of ice molecules in the solvent. It is clear that the existence of a temperature of maximum contraction indicates a difference in the proportion of the bulkier ice or steam molecules. This firmly establishes the ternary theory of water.

POLYMERIC ISOMERISM

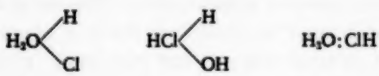
The interesting paper of Armstrong (1908) deals with the possible existence of isomeric water molecules of equal complexity but of different structure. Water itself is supposed to be a complex mixture of active and inactive molecules; the active molecules being either simple monad-*hydrone* (OH_2) molecules or *hydrone-hydronol* (briefly, hydronol) molecules  ; the inactive, the closed systems which are formed by *association* unaccompanied by *distribution* of two or more simple molecules such as



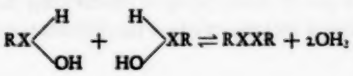
The dissociative change

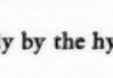
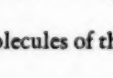
$$(H_2O)_n \rightleftharpoons nH_2O$$

is of constant occurrence in water and is largely conditioned by the presence of dissolved substances. When a substance such as HCl dissolves in water the following complexes are produced



of which the first two are the only effective forms, the last being inactive as long as it remains closed. Through the agency of hydrol dissolved molecules may be converted into inactive isomerides:



On dilution there is an increase in the number of effective composite molecules, ascribable to the diminution in the activity of the solvent water which is *most active when present in small amounts* (as it is then present in the monadic form or in association as hydrol). Thus we would expect to find molecules of the active type  in weaker solutions for in these the monads of hydronol are scarce and the solvent has less tendency to withdraw hydrol from the complex. Conductivity in concentrated solutions is conditioned mainly by the hydrolyzed solute  but in weak solutions by hydrolated solute  . Since hydrolysis takes place more readily in the more concentrated solution, it is supposed to be conditioned by molecules of the hydrone type  , not by the isomeric hydrolated complexes. When discussing the behavior of non-electrolytes on a later page (p. 88) Armstrong mentions that pressure diminishes the rate at which cane sugar is hydrolyzed and the degree of hydrolation and hydronation of sugar is diminished by an increase of hydrol and hydrone resulting from pressure dissociation. The original paper must be consulted, for it is obscure on several points, but we have given enough of Armstrong's argument to illustrate the possibility that the "trihydrol effect" in biology may be traced to the distribution of the water ions in the molecules in protoplasm rather than to a direct effect of the water polymers.

A word must be said concerning Armstrong's treatment of surface effects which, of course, are of peculiar importance in general physiology. Brownian movement effects, the evolution of heat on moistening powders, the decoloration of solutions by charcoal, the flocculation of colloids by salts, and the "dead space" of Liebreich are discussed from the standpoint that all surfaces in contact with water are hydrolated and in virtue of this condition they influence hydrolated molecules in the liquid, withdrawing elements of hydrol from them. Thus in Liebreich's phenomenon the dehydrolation of molecules near the surface of the tube (in "dead space") explains the greater activity toward the axis. But it is impossible to accept Armstrong's statement (p. 95) that "the phenomena of surface tension may be attributed to the proponderance of monads in the surface layer of a liquid," for we have seen that the trihydrol molecules of small density collect at the surface. Armstrong has previously stated that the monads are quite dense since they are concentrated by pressure, which is inconsistent with his view of surface films. Bousfield and Lowry's work later indicated that the water monads have less density than dihydrol. It is unfortunate also that Sutherland's calculation that water film is pure trihydrol is based entirely on the binary theory. One of us (T. C. B.) is at present investigating the appearance of algae on the surface of ice water and steam water, and it is found that *Ulothrix* on the surface film does not show the polymer effect seen in *Spirogyra* below the surface.

DEGREE OF ASSOCIATION

Guye, in the Symposium of the Faraday Society (1910), summarizes his work on the association of water and of other compounds. He asserts that molecular polymerization in the liquid state depends essentially upon chemical constitution and

that this fact is exemplified by association in the homologous series of aliphatic acids and alcohols. There are certain groups capable of polymerization (OH, CO, CN, NH_2, NOH, $CONH_2$), and substances with two polymerizable groups that this might lead to the formation of highly complex and stable polyhydrols.

In connection with Guye's discussion of groups capable of association it is of interest to note that Bingham and Spooner (1931) have recently listed polar groups

TABLE 4

The Association Factor of Water, x in $n(H_2O)_x$, According to Various Authors

Raoult (1885), $x = 2$.
Vernon (1891), typical water, $x = 2$; aggregate at 4°C., $x = 4$.
van Laar (1899), $x = 2$.
Sutherland (1900), steam, $x = 1$; water, $x = 2$ and 3.

Duclaux (1911).

TEMP.	FROM COEFFICIENT OF EXPANSION	FROM COMPRESSIBILITY AND TEMPERATURE	FROM EXPANSION AND SPECIFIC HEAT
Apparently at 0°C.	$x = 9$–12	$x = 6$–23	$x = 12$

Guye (1910).

TEMP.	FROM COHESION FORMULA OF DUTOIT	SURFACE TENSION (RAMSEY AND SHIELDS)	SURFACE TENSION (RAMSEY AND INNES)
0°C.	$x = 2.52$	$x = 3.81$	$x = 1.71$
60°	2.18	3.00	1.52
100°	1.90	2.66	1.40
120°	1.85	2.47	1.35

Tammann (1926), highest polymer in water, $x = 9$ or 6.
Pennycuick (1928), $x = 6$.
Stewart (1931), aggregate may contain hundreds of molecules.
Kinsey and Sponsler (1933), $x = 2$.
Bernal and Fowler (1933), water structure based on a 4-conditioned aggregate, $x = 5$.

Bingham and Stevens (1934).
Ordinary water, $x = 2.5$. Heavy water, $x = 1.34$.

are as a general rule more highly polymerized than those with only one such group. This leads to the highly interesting suggestion that dihydrol is more apt to polymerize than hydrol, and under certain conditions it is possible to imagine which accentuate association notably, OH, COO, NH_2, CO, Cl and SH.

Guye regards the association factor derived from the relation of molecular weight and surface tension as only approximate, and for calculation of the molecu-

lar weight of water he uses the formula of Dutoit and Mojoiu for liquids of mean volatility:

$$M = \frac{0.6\,T\,(4.8 - \log P)}{a^3},$$

where a is the specific cohesion (defined as $a = hr$, h being the height to which a liquid ascends in a tube of radius r, provided that the height h does not exceed 1,500 mm.). This formula gives a somewhat lower association factor (Table 4) than that derived from Eötvös' equation (*vide supra*). Guye concludes, however, that the coefficients from Dutoit's formula agree with the view that water at 0°C. is composed mostly of trihydrol and at the boiling point mostly of dihydrol. In considering these association factors (Table 4) it should be remembered that the factor for the highest polymer will be higher than the average factor indicated.

Rosenstiehl (1911), who studied the polymerization of water of crystallization, states that trihydrol is the commonest form of water in crystals containing large amounts of water and at low temperatures when the crystals separate out it is the most stable form of water. If this view were correct, one should expect that the molecular structure of trihydrol could be demonstrated by x-ray analysis. However, Chadwell (1927) points out that x-ray analyses of water of crystallization do not support Rosenstiehl's theory. Pennycuick (1928) believes the water of crystallization in a number of salts to exist as hexahydrol rings, $(H_2O)_6$, and this is in agreement with his view that the polymer in liquid water is also $(H_2O)_6$.

The most outstanding paper on the degree of association of water is undoubtedly that of Duclaux (1911) who, using new methods, calculated association factors much higher than 3 (Table 4), the factor assumed for trihydrol. He pointed out that on account of the lower density of dissolved ice, the proportions of the polymers should vary with the depth of water in a vertical tube. Furthermore, as a result of pressure differences the concentration of liquid ice will be lower toward the bottom of the tube, and it will be related to the internal pressure of the liquid by the equation

$$\frac{dc}{c} = -4.5 \times 10^{-6}\,MdP$$

where M is the molecular weight of the dissolved ice, C its concentration, and P the pressure (T = 0°C.).

Duclaux also points out that the molecular weight of a substance may be calculated from its coefficient of expansion, α. The equation is as follows:

$$\frac{0.97\alpha}{\alpha + 68 \times 10^{-6}} = 1 - 0.000785M$$

The coefficient of expansion of hydrol is unknown, but by assigning the probable limits 0.0004 and 0.0006, Duclaux calculates a molecular weight for dissolved ice of 164 or 218 depending upon the value of the coefficient used. These values yield the formulae $(H_2O)_9$ and $(H_2O)_{12}$, with molecular weights of 162 and 216, respectively.

As calculated from an equation relating the compressibility of water to temperature the molecular weight of dissolved ice lies between the limits 120 and 410, (suggesting $(H_2O)_6$ and $(H_2O)_{22}$) and depends upon the values assigned to the compressibility coefficient of hydrol. The value $(H_2O)_{23}$ is one of the highest ever proposed for associated water. However, the groups of water molecules postulated by Stewart (1931) may contain hundreds.

By combining the expansion formula with specific heat data Duclaux developed a third method of calculation on the assumption that the specific heat of ice is 0.6 and that it increases slowly with temperature. This treatment assigns to dissolved ice the formula $(H_2O)_{12}$. In all of the above cases, Duclaux admits he assumed that the density of ice does not

change on solution, and that (as Sutherland reasoned by analogy) a change probably does take place. Therefore, the exact figures of Duclaux are only of doubtful validity, but it is interesting to note that all of his values indicate that liquid ice is a much more complex molecule than trihydrol.

The degree of association of water has also been calculated from the depression of the freezing point when a solute of known molecular weight is introduced. In this method it is assumed that the solute is non-associated in solution, that no molecular complexes are formed by the solute and the solvent, and that the association of the solvent is not changed by introduction of the solute. The association constants calculated in this manner vary with the solute and are, in general, lower than those found by other methods. Friend (1933) gives association factors of water found by introducing various substances as follows (from Oddo): phenol, 1.18; p-toluidine, 2.00; chloracetic acid, 1.40; cyamide, 1.64; acetic acid, 1.73. If these constants were accurate, there would be a large amount of monohydrol in water at 0°C. However, other considerations indicate that these values are too low, and the value generally assumed is considerably higher. For example, the equation of Walden (see Friend, 1933) indicates that phenol, assumed to be non-associated in this calculation, is associated to a considerable degree.

MAGNETIZATION OF WATER

It seems unnecessary to mention all of the numerous papers dealing with the association of water written since the Symposium of the Faraday Society in 1910; only those which bring forward points of special interest, such as those of Duclaux, will be mentioned. Piccard (1912) was one of the first to follow changes in the magnetization coefficient of water with temperature. These changes he explained by assuming that water at ordinary temperatures is a mixture of two substances.

The diamagnetism of water at different temperatures has received very careful study recently by Wills and Boeker (1932) who used a specially devised manometric balance of great sensitivity. Piccard had found that the specific susceptibility of water increases with temperature, while the results of others indicate exactly the reverse. It is probable that these discrepancies are due in part to the *thermal history* of the water samples investigated. Wills and Boeker give two curves, one of which, obtained from water which had stood for several days in contact with helium gas, is a true equilibrium curve, indicating an increase of susceptibility with temperature. The other curve, indicating a decrease in susceptibility with rising temperature, was obtained from water which had been boiled vigorously for fifteen minutes immediately before the experiments. The authors state that the difference between the curves cannot be ascribed to errors of observation or to peculiarities of the apparatus, but might be explained "on the assumption that polymerization changes in water produced by variation in temperature required for their completion a considerable time." If this hypothesis is true, it affords valuable support to our assumption that water from steam and from ice possess different degrees of polymerization for a limited time. Certainly if the mere thermal history influences the degree of polymerization, an actual change of state, from vapor on the one hand and ice on the other, should have even more pronounced influence on the resulting water. As will be shown later (H. T. Barnes, 1929) the ice-forming power of water at low temperatures indicates a considerable lag in the association equilibrium. In a more recent paper Boeker (1933) has repeated these experiments, using several non-associated liquids. In none of the experiments with non-associated liquids did he obtain a hysteresis effect which might be due to the thermal history of the liquid. This strongly supports the theory that the equilibrium ratio of the water polymers is

not reached instantaneously, and it shows that the hysteresis effect is not due to a defect in the apparatus used. On the other hand a hysteresis effect is not described by Cabrera and Fahlenbrach (1933) in their paper on the variation of the diamagnetic constant of water with temperature. The work of Wills and Boeker helps to explain Hegarty and Rahn's (1934) discovery that recently condensed water retards bacterial growth.

PRESSURE AND COMPRESSIBILITY STUDIES

The important studies of Bridgman from 1912 onwards on various modifications of ice under pressure have been succinctly summarized by Honigmann (1932). As Honigmann points out, the melting curves of the special varieties of ice, other than Ice I, do not, on the basis of the Tammann interpretation, necessarily involve great changes in molecular complexity. Bridgman's work indicates that −22°C. is the minimum freezing point of water under any equilibrium conditions, but Gortner (1930) reports the presence of liquid bound water in colloids and tissues far below this critical temperature (explained by the capillarity conditions).

Bridgman showed that at 2500 atmospheres pressure the density-temperature curve of water has no maximum, but is a straight line, as for normal liquids at atmospheric pressure. This is ascribed to the destruction of the polymers at very high pressures. H. T. Barnes (1928, p. 26) states that the temperature of maximum density recedes towards zero at a rate of 0.025°C. per atmosphere. This lack of a maximum density is comparable to that obtained with concentrated salt solutions (Bousfield and Lowry, citations above). In this connection it might be mentioned that sea water shows no maximum density, and it would be very interesting to re-examine other properties of sea water in view of the influence of salts on the degree of polymerization. In this connection it is deplorable to note that oceanographers ignore the polymerization factor in sea water.

It is known that as pressure is increased the minimum of compressibility of water at 50°C. is not shifted toward lower temperatures but is wiped out where it stands at 50°C. This is not consistent with the binary theory of Röntgen and Sutherland, but is consistent with the ternary theory of Callendar and Bousfield and Lowry. This theory assumes that above 50°C. monohydrol (possessing, like trihydrol, a greater bulk than dihydrol) becomes important in concentration.

The ternary theory received further support in the careful compressibility measurements on solutions of urethane made by Richards and Palitzsch (1919) by means of a glass piezometer. Urethane is very soluble and does not dissociate or associate, and is therefore an ideal substance for this work. It is well known that all aqueous solutions show a marked diminution in compressibility with increasing concentration, even when the dissolved substance is more compressible than pure water. In spite of the fact that alcohol has twice the compressibility of water, the addition of less than 20 per cent alcohol to water at room temperature diminishes the compressibility of the solution. This is probably caused by the destruction of the more compressible trihydrol molecules by the alcohol (as van Laar (1899) suggested, but cf. Bancroft and Gould (1934)).

The compressibilities of urethane solutions were measured at constant temperature (20°C.) over a pressure range of 100 to 300 megabars. With increasing concentrations of urethane the compressibility decreased rapidly from 43.25×10^{-6} (the compressibility of pure water) to 38.91

$\times 10^{-6}$ at 34 grams per 100 grams of water. From this point the compressibility increased at first slowly and then more rapidly; at the highest concentration measured (127.3 grams per 100 grams of water) the compressibility was 40.80×10^{-6}. The conclusion is that the effect of dissolving anything in water is to dissociate part of the trihydrol present, thus diminishing the compressibility. The rise in the compressibility of urethane solutions with increasing concentration above 34 grams per 100 cc. can be ascribed to the increasing concentration of monohydrol.

Measurements of solution volume also indicated that urethane causes the breaking down of trihydrol into dihydrol, and this effect diminishes as the concentration of trihydrol is decreased. The surface tension shows a very marked falling off for low concentrations, but in 40 per cent solutions (from which the trihydrol has been eliminated) the surface tension decreases far less rapidly. The viscosity rises rapidly with concentration, showing that the viscous urethane more than compensates for the diminished amount of trihydrol. In brief, the results of Richards and Palitzsch are precisely what one would expect if water contained an appreciable amount of trihydrol in dilute solutions and an appreciable amount of monohydrol in concentrated solutions (as Armstrong maintained), dihydrol being present under all conditions. This work was extended to aqueous solutions of urethane, ether, alcohol, and methyl acetate by Richards and Chadwell (1925). On the basis of solution volumes they obtained percentages for polyhydrol in water which agree rather closely with those of Whiting and Sutherland, but which were somewhat lower than those of van Laar (1899). Moreover, this interpretation is supported by the recent paper of Freyer (1931) on the physical properties of liquids as revealed by compressibility and the velocity of sound in solutions of alkali halides.

Freyer considers the possibility that the presence of ions may change the condition of aggregation of the water molecules, *i.e.*, may shift the trihydrol-dihydrol-monohydrol equilibria. He suggests that any effect of this kind would actually be brought about as a result of hydration. For a given concentration those solutions with the most highly hydrated solutes will have a lower compressibility, and the contraction of water is inversely proportional to the mean radii of the ions producing it. This, of course, follows from the greater intensity of the electric field about the ions of low atomic weight and small radii, which results in a greater attraction of the water dipoles for the ions—the so-called *electroconstriction*. It is known that a decrease in compressibility is accompanied by an increase in the velocity of sound through water and that an increase in density accompanies a decrease in velocity. In the case of the most important salt, NaCl, the compressibility greatly predominates, and the velocity of sound through NaCl solutions increases rapidly with concentration. This predominance decreases in the following order:

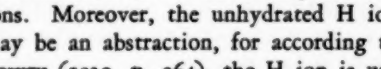
$$NaCl > KCl > NaBr > KBr$$

It would be of interest to reconsider the velocity of sound in sea water and body fluids on this basis.

ACTIVITY IN RELATION TO HYDROGEN IONS

The chemical activity of water is considered at some length by Rice (1923), although not in connection with the problem of polymerization. Rice points out that stoichiometrically neutral water may not be neutral catalytically. Water is considered neutral when the total hydrogen and hydroxyl ion concentration are

equal and since the unhydrated ions are present in very minute amounts the concentration of hydrated ions will be equal at this point. But the concentration of unhydrated ions will not be equal for the affinity of H^+ for water is greater than the affinity of the OH ion; thus a stoichiometrically neutral solution will be "alkaline" catalytically, for the unhydrated H ion is assumed to be the active form. Making the solution acid stoichiometrically (pH 5) makes the concentration of the two unhydrated ions equal and the solution will have a *minimum catalytic activity* at pH 5. That the unhydrated H ion is the active catalyst (as first proposed by Lapworth) is suggested by the fact that H ion in some instances catalyses faster in alcohol than in water and by the stability of acetates between pH 4.7 and 5.1, etc. Rice points out that although many H ion catalyzed reactions have a value of approximately 20,000 calories for the quantity Q in the Arrhenins equation, we cannot calculate the change in concentration of the unhydrated H ion with temperature for we do not know the concentration of simple water molecules present nor the number of water molecules combined with the hydrated H ion. Further investigation is needed to show whether the degree of polymerization of water will effect the concentration of the active unhydrated H ions. Moreover, the unhydrated H ion may be an abstraction, for according to Lowry (1930, p. 964), the H ion is unknown except as an internal parasite in a water molecule. The free H ion is a naked proton and has only a transient existence as a positive ray in a vacuum tube. The usual equation $HCl \rightleftharpoons H:Cl$ should represent a transference of a parasite from one host to the other.



Moreover, as Prof. H. S. Harned has informed us, the reaction $H^+ + H_2O = H_3O^+$ has a free energy of $-300{,}000$ calories (approx.), and therefore, the concentration of free proton would be too small to be catalytically significant.

Gortner, Hoffman, and Sinclair (1928) consider the possibility that one should not ignore the denominator, as is usually done, in the equation for the dissociation of water into H and OH ions, for they suggest that possibly only monohydrol dissociates, and of course, its concentration is relatively small at biological temperatures. The equation they suggest is

$$(H_2O)_n \rightleftharpoons (H_2O)_3 \rightleftharpoons (H_2O)_2 \rightleftharpoons H_2O \rightleftharpoons H^+ + OH^-$$

If only a small amount of monohydrol is present, there might be an appreciable change in its concentration due to dissociation, in which case the concentration of H_2O could not be disregarded as negligible in calculations of K_w. However, they consider that there is no means of determining the relative proportions of water molecules in their different degrees of polymerization. It is probable that the pH change of pure water with temperature is conditioned by the temperature shift in the polymer ratio.

Pennycuick (1928) states that the ions of water can not be dissociated from the contiguous water molecules which brought them into existence, or in other words that these ions are always hydrated. In the same way the hydrogen ions of acid solutions are always directly associated with the surrounding water molecules. A hydrogen ion would be more correctly written as $[H(OH)H(OH)H]^+$ and a hydroxyl ion as $[(OH)H(OH)H(OH)]^-$, where the ionic groups are continually increasing or decreasing the amount of water with which they are associated. Now, in these hydrated ions it is impossible to say which of the removable hydrogen nuclei (four in the above formula) or which of the removable hydroxyl radicals (two in the above formula) represents the hydrogen or hydroxyl ion. We must assume the whole hydrate to carry the positive or negative charge. It will be noticed that

while other ions, such as Na^+ or Ca^{++} (undoubtedly hydrated), have an individual existence in aqueous systems, the hydrogen and hydroxyl ions in such systems do not exist as unchanging individuals, but, owing to the nature of the solvent, the particular nucleus which may be arbitrarily taken as representing a hydrogen ion at any one instant may exist at another as part of a water molecule, the liberated hydrogen nucleus becoming the hydrogen ion. Perhaps we have here the most common example of tautomeric hydrogen. The catalytic effect of the hydrogen ion on hydrolyses in general is probably intimately connected with this tautomeric change; for a water molecule undergoing such a change would be in a peculiarly unstable (loosened) condition, and as such would be particularly open to internal rupture.

This unique position of the H ion in water led Bernal and Fowler (1933) to propose a new theory of the structure of water (see below). They recognize that the H ion is not a naked proton but must be firmly attached to at least one water molecule as $(OH_3)^+$, the oxonium ion, in which the extra proton is attached near one of the two vacant tetrahedral positions among the electron orbits, the whole structure being similar to the ammonia molecule, NH_3. According to quantum mechanics an $(OH_3)^+$ ion in sufficiently close contact with a water molecule (OH_2) need not retain its extra proton but can transfer it to the other molecule. Thus the proton jumps (in the sense of Hückel) to and fro from one to the other when the configuration of the two molecules is favorable and this leads to a large extra drift down the field (the unexplained mobility of the H ion). Apparently Latimer and Rodebush (1920, p. 1432) were the first to suggest this explanation.

INFRA-RED ABSORPTION

Mention must be made of the infra-red absorption of ice described by Plyler (1924). In this study plane polarized light was allowed to fall upon the ice crystal, and the percentage transmission was determined. Plyler found that it was impossible to obtain clear ice by freezing distilled water between glass plates, but very clear pieces of ice were obtained by cutting sections out of a block of artificial commercial ice. It was necessary in this work to use single crystals, because the spectral transmission is less when the absorbing direction is parallel than when it is perpendicular to the direction of the light. Large crystals were obtained by keeping commercial ice slightly below the freezing point for two months. This crystal growth has not been explained but Altberg and Troschin (1931) have found single crystals half a meter in size in mountain caverns. The location of the absorption bands for ice (for the extraordinary ray) were 0.81, 0.92, 1.06, 1.29μ and for water at 0°C., 0.74, 0.84, 0.98, 1.21μ. Plyler shows that the values for water vapor, water at 100°C. and 0°C., and ice give a smooth curve when plotted against Sutherland's estimated percentages of trihydrol at these temperatures. The increasing concentration of trihydrol shifts the bands toward the longer wave lengths.

Collins (1925) made a special study of changes in the infra-red absorption spectrum of liquid water between 0°C. and 95°C. (Table 5). As the temperature was increased he found a shift toward shorter wave lengths and a marked increase in the magnitude of maximum absorption for bands at 0.77, 0.98, and 1.21μ. Collins explains these changes qualitatively on the hypothesis that water is a mixture of at least two kinds of molecules whose relative amounts change with

temperature. Neglecting the effect of the hydrol (a questionable procedure) he suggests that the bands in the spectrum of dihydrol have slightly shorter wave lengths than those of trihydrol. A comparison of the spectra of water vapor, water, and ice indicates that the bands of dihydrol near 1.45 and 1.96μ are not so intensive as corresponding bands of trihydrol. The intensity of these bands increases with increasing complexity of the molecule, while in bands at shorter wave lengths the reverse is true. Splitting of trihydrol into 1½ molecules of dihydrol might explain the increase in the active absorption bands of dihydrol. Plyler and Craven (1934) announce new bands at 3.30μ, 5.56μ and 5.83μ. They consider that the bands are made up of two or more components which vary in intensity with temperature. Ellis and Sorge (1934) report that water samples from condensed steam and fresh ice have similar infra-red bands. However, ice (almost 100 per cent trihydrol) and water (37 per cent trihydrol) have similar bands with differences in the second decimal place only, so that a 10 per cent polymer difference would not be clearly indicated by their method. Other physical tests, on the contrary, demonstrate differences in ice and steam water (see below) (T. C. Barnes, 1934b).

Ellis (1931) finds infra-red absorption bands in the liquid and solid states which are absent in the vapor and his results support the theory of Kinsey and Sponsler (1933) that the units H_2O_2 and H are present in liquid water linked in groups or a lattice-work.

TABLE 5

Location of Maximum Infrared Absorption Bands in Liquid Water (Collins, 1925)

At 0°C.	.775		.985	1.21	1.45	1.96μ
At 95°	.74	.845	.97	1.17	1.43	1.94μ

DEVELOPMENTS IN THE THEORY OF WATER STRUCTURE, 1926–1929

Tammann (1926) considered the molecular complexity of water in detail based on the presence of a type of molecule of large volume and possessing the reticular structure of Ice I. He had previously (Tammann, 1910) suggested that ice exists in several forms which fall into two groups: (a) lighter than liquid water and (b) heavier than liquid water. Ice belonging to the first group separates only from water rich in polymolecules while ice of the second group separates only from water containing an abundance of simple molecules. In the later paper (1926) he calculates the proportions of Ice I in liquid water (cf. Table 1). On the assumption that molecules of the four kinds of ice are present in water there are four types of water molecules polymerized or isomeric with each other, but the molecules resembling Ice I are the only ones that can be clearly recognized. At high temperatures and low pressures water probably contains molecules of $(H_2O)_2$ which were recognized by Nernst. The determination of the concentrations of molecules of type 1 permits the thermodynamical calculation on their molecular weights—$(H_2O)_9$ in case these molecules dissociate into $9H_2O$, and $(H_2O)_6$ in case they dissociate into $2(H_2O)_3$. His consideration of the temperature-volume curve of water is similar to Sutherland's, but Sutherland's paper came to his attention after his own calculations had been made.

Baker (1927) reports some interesting experiments on molecular association, showing that association like dissociation of molecules takes place much more slowly for liquids than for gases. In liquids the equilibrium can be easily disturbed by even a slight change in temperature and the return to normal conditions takes a long time, sometimes even months. The presence of a catalyst like charcoal increases this lag in the equilibrium. Thus a water sample having a vapor pressure of 2.5 mm. was heated for 48 hours at 80°, and a day later its vapor pressure was 4.3 mm. West and Menzies (1929) find a slight change in the vapor pressure of water after thermal treatment even in the absence of a catalyst but Wright and Menzies (1930) do not observe this effect in acetic acid. The vapor pressure, however, is not always a significant indicator of polymerization but might show a difference in monohydrol (see below).

A new method of separating polymers in liquids has been proposed by Berkeley (1927) who believes that the separation of constituents of a liquid might take place in a centrifuge tube rotated at a high velocity. Isotopes might also be segregated by this method. It would be of great interest if separation of water polymers could be partially effected in this way although Longinescu (1929) points out that Svedberg's ultra-centrifuge (42,000 × gravity) will not separate molecules unless the difference in molecular weight is some ten thousand fold. Perhaps the new centrifuges of Svedberg (1934) and Beams, Pickels and Wood (1934) will ultimately develop fields of sufficient magnitude.

H. T. Barnes (1926) discusses colloidal forms of water in Alexander's *Colloid Chemistry*. We have already seen that ice molecules in water influence the shape of the density, specific heat, and viscosity curves with temperature. He points out that the beginning of the true colloidal form of water is the formation of trihydrol from dihydrol at temperatures below 60°C. The final ice molecule, trihydrol, is devoid of all crystal form above 0°C. and remains invisible until the freezing point is reached. At this temperature it becomes sufficiently concentrated and the molecular groups become of sufficient size with relation to the remaining dihydrol molecules to affect light reflected from the depths of the water, thereby producing a very delicate change of hue. Also the vivid color of iceberg ice and of water from glaciers is caused by the molecular structure. Since the freezing process eliminates all foreign matter from clear ice this scattering of light cannot be due to dust particles. H. T. Barnes also states that freshly formed ice is in the nature of a great clot which undergoes structural alterations. The structure of ice depends upon its rate of formation; ice formed slowly by natural means is composed of large crystals, but ice formed rapidly from slightly super-cooled water is composed of fine crystals. The best biological results are obtained with large crystal ice.

It is interesting to note that the moisture content of organic liquids results in the appearance of colloidal particles (colloidal water and ice in cooled chloroform); but as H. T. Barnes points out we are only on the threshold of our knowledge of the action of collodial water and "*the influence of these liquid aggregates on chemical action has been completely overlooked in the past but may be the real seat of the chemical activity of water.*" In H. T. Barnes' book *Ice Engineering* (1928), half of which is devoted to the pure physics of ice and water, the following important statement occurs: "It is highly probable that perfectly pure dihydrol would be chemically inert, ... if we could find a way to destroy trihydrol molecules in water that fluid would no longer be useful to living organisms nor could it ever freeze."

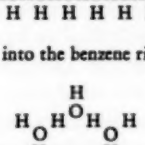
This theory that the activity of water is due to the trihydrol is supported by the effect of ice water on *Spirogyra* and *Euglena*. As has been discussed above, Armstrong takes the opposite view, that the water monads are more active, but according to Armstrong their activity may express itself in the *dehydrolating* and consequent inactivating of dissolved molecules of other substances, which is not incompatible with the hypothesis that water poor in

trihydrol but rich in monohydrol would not be as active as ice water and this might explain the discovery of Hegarty and Rahn (1934) that recently condensed water retards the growth of bacteria. It is probable that the effect of water polymers will be largely conditioned by the type of chemical reaction influenced and the nature of the solute molecules.

Pennycuick (1928) states that the stable polyhydrol of water is not di- or tri- but is hexahydrol. The water molecule is tetrahedral in structure and has a strong tendency to form chains of varying length. Due to the angles of the tetrahedron, a six membered chain may become closed. Such a ring bears a strong resemblance to the inactive benzene ring, and it would be much more stable than any of the lower polymers. One might consider water to be a mixture of relatively stable hexahydrol rings and of lower unstable polymers of continually changing size. He states that "the unique properties of water—high dielectric constant, the solvent activity, remarkable and general catalytic activity, and even the physiological importance must finally be traced to the structure of the individual molecule itself—in most respects unique." He points out that the molecule is polar, i.e., unsymmetrical and a tetrahedron where the electrons are in pairs at the corners (Fig. 3), due to the tetrahedral structure of the saturated oxygen atom. Hence water can attach itself to other molecules either through its own negative pairs or through its own positive hydrogen nuclei, which accounts for the positive and negative affinity of the water molecule. The various properties of water can be explained on the assumption that the molecules are held together solely through the attractions between the H nuclei and the O lone electron pairs. Thus polar chains are formed.

$$+\ \underset{\text{H H H H H H}}{\text{HOHOHOHOHO}}\ -$$

which may close into the benzene ring structure



in harmony with the hexagonal structure of ice.

Pennycuick regards association in the liquid state as a "perfectly general" phenomenon and considers that the equation of state of van der Waals can be deduced equally well by substituting the idea of molecular association for the conception of internal pressure. He cannot accept the view that water is a mixture of mono-, di- and tri-hydrol, each having a statistical average existence because such a liquid would behave as a normal quasi-associated system; rather he considers water as a mixture of relatively stable compound molecules of benzene ring structure in a normal solvent. Stewart (1931), Bernal and Fowler (1933), and Kinsey and Sponsler (1933) also favor this notion of a molecular group and not a mixture of three molecular types but Rao (1934, p. 498) shows that water is a ternary system as revealed by Raman spectra.

Longinescu (1929) has recently published a stimulating paper on the nature of molecular association, which concept he attributes to Louis Henry. Longinescu points out that in spite of all attempts to describe water as a mixture of simple, double and triple molecules, etc., not a single type of these molecules has been isolated. To explain this "failure" (as he terms it) the hypothesis was invented that the associated molecules are in unstable equilibrium so that they dissociate and come together again with great rapidity. In collaboration with Chaborski he puts forward an alternative hypothesis that molecular "association" is in reality a phenomenon of molecular *concentration*. In place of the idea of molecular complexity they introduce the notion of molecular accumulation. Thus water which shows the highest degree of molecular association has the greatest molar concentration and hence the highest degree of accumulation. Liquids, like gases, consist solely of simple molecules and the greater a liquid is "associated," the greater the number of these molecules in equal volumes. In numerous cases the degree of association is one-tenth of the molar concentration. The author does not attempt a detailed refutation of the numerous lines of evidence for the trihydrol hypothesis.

LAG IN ATTAINMENT OF EQUILIBRIUM OF POLYMERS

More recent developments of the trihydrol hypothesis are reported by H. T. Barnes (1929) concerning the ice-forming power of water. He shows that water may be exhausted of its ice-forming power by experimental means (Fig. 1). For instance, water was cooled in a tank at ten to fifteen degrees below freezing (air temp.). After the expiration of definite

time periods the ice was removed and measured, and the water was allowed to form fresh ice. In a typical experiment under given conditions the first half hour yielded a full pail of ice. However, another full pail of ice was not formed for another full hour, and still another two hours were required for the formation of the third full pail of ice. For four hours afterwards there was no ice production, especially at low temperatures. When the exhausted water is rewarmed to 20° and then cooled, it will freeze readily, indicating that the establishment of polymerization equilibrium is more rapid at higher temperatures.

Wills and Boeker (1932) (see above) detect a polymer lag with a diamagnetic method. Menzies (1934) is skeptical of the physical evidence, such as that of

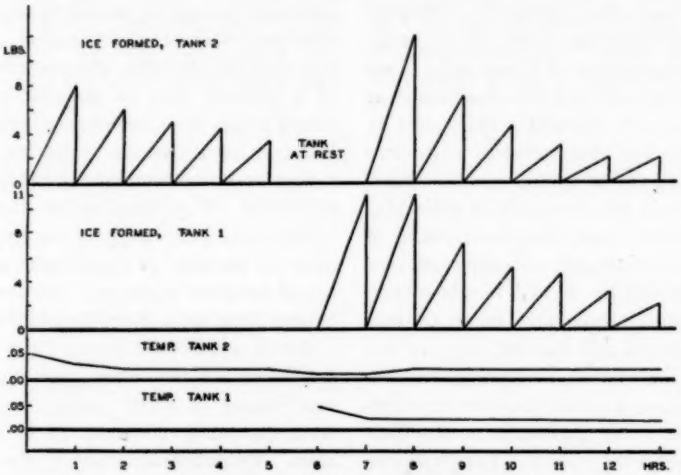


FIG. 1. EXHAUSTION OF THE ICE-FORMING POWER OF WATER

(From unpublished data of H. T. Barnes, cf. H. T. Barnes, 1929.)
The graphs show the amount of ice formed per hour in large tanks. The ice was removed and measured each hour and the remaining water allowed to form new ice. Stirrers in the water and electric fans in the air above were running continuously except for the fifth and sixth hour when tank 2 was at rest. The interval permitted enough "trihydrol" to reform so that this partially exhausted water had recovered during the seventh hour as judged by the quantity of ice formed which was the same as in the control tank 1, started at the beginning of the sixth hour. These experiments can be interpreted on the assumption that at 0° two hours is required for the attainment of the equilibrium between polymers.

produced; the ice-forming power of the water had been temporarily exhausted. This interesting result can be explained on the colloidal theory; a nucleus is required for the colloidal ice mass, and after removal of these nuclei the formation of further ice is rendered difficult. This passive state of water can be explained, also, on the ground that time is required for restoration of the trihydrol in solution.

Barker (1927) (see below) but suggests that the biological method may be more sensitive.

RECENT WORK ON ASSOCIATION

Stakhorski (1930) has recently applied the equation of Kordes' Law to water and its mixtures with another substance. He uses an equation of the following form

$$X = [M_b \cdot a\,(T - T_s) \cdot T_b / M\,b\,(T_b - T_s)\,T_s]$$

in which X is the association factor, a and b are concentrations of the two components A and B and T_a, T_b, and T_e are the melting points of A and B and the eutectic mixture. He concludes that the application of Kordes' Law confirms the theory that water is a typical associated compound.

Stewart (1931) has considered the nature of the molecular association of water as revealed by his x-ray diffraction studies. He gives the x-ray diffraction intensity angle distribution for water and its variation for temperatures of 2° and 98°. Two important periodicities are established at 3.24 and 2.11 A. U. and a third at 1.13 A. U. The first one decreases with temperature and the second increases. Stewart suggests in his discussion of molecular polymerization that the description of association involving complexes of two or three molecules should be abandoned in favor of the molecular group conception (cf. Bernal and Fowler, 1933). According to Stewart the conception of molecular complexes explains neither the existence of the x-ray periodicities nor their change with temperature. The groups of water molecules postulated by Stewart (cybotactic condition) may contain hundreds and perhaps thousands of molecules in each, having a temporary existence as individuals with ill-defined boundaries and possessing an optimum size and an internal regularity determined by the temperature and molecular forces. A detailed description of the molecular arrangement in water from x-ray data is not at present possible, yet it simulates the crystal structure.

An entirely new aspect of the polymerization problem is considered in the recent paper of Plotnikov and Nishigishi (1931) dealing with the rhythmicity of the trihydrol equilibrium. When the longitudinal scattering of a carbon arc passed through an alcohol solution was photographed at minute intervals, a periodic fluctuation of the amount of scattering was observed. The same effect was obtained with other substances at various temperatures. In aqueous solutions this rhythmicity can be interpreted as a steady interchange between different sizes of the molecular complexes of water, a fluctuation around the point of chemical equilibrium. Large sugar molecules increase the scattering and decrease the amplitude of the water fluctuations. Plotnikov suggests that this phenomenon is one of a general class of periodic processes which might be of importance for biology. It is concluded that the scattering effect is a very sensitive method for studying the properties of polymolecular complexes. These experiments support our hypothesis that the association equilibrium is not attained instantly as many physical chemists believe from an *a priori* line of reasoning.

Bernal and Fowler (1933) have recently published an important paper giving a new theory of water and ionic solution with particular reference to H and OH ions. Their consideration of the spectroscopic molecular model of H_2O, of the crystal structure of ice and the density of water lead them to propose an irregular 4-coördinated structure for water which accounts for the positions of the maxima of the x-ray diffraction curves. The structure of water has three forms, i.e. Water I: ice-tridymite-like (4-conditioned) at temperatures below 4°; Water II: quartz-like (4-conditioned) in the range 4°–200°C.; and Water III: ammonia-like, close-packed occurring in the range 200–340°C. Water I (Fig. 2) is the fundamental structure which is distorted by higher temperatures, the aggregate of greatest biological interest being the quartz type (Fig. 2) since it is the form over the physiological temperature range.

The arrangement of an H_2O molecule of 1.4 A radius surrounded by four others in a more or less regular tetrahedron is that found in ice and follows from the quasi-tetrahedral angle of the H_2O molecule (cf. Debye (1929) for the structure of monohydrol). The proton near the surface of one molecule lies opposite the empty place in a neighboring molecule, i.e., in a place where the proton would be in such a molecule as CH_4. In silica, SiO_2, where a similar four-fold coördination holds, there are three main crystalline forms: cristabolite, tridymite, and quartz. Of these the tridymite corresponds to ice, and water is simply an irregular version of this. The three forms pass continuously into each other with change of temperature. Like Stewart (1931), Bernal and Fowler state that there is no question of a mixture of volumes with different structure; at all temperatures water is homogeneous, but the average mutual arrangements of the molecules resemble water I, II and III in more or less degree. The sequence is one of increasing rotatory and translatory molecular movement, and the consequent diminution of the dipole forces of cohesion of the liquid. The break down of the empty ice-like structure is a decrease in volume to water II, followed by an increase of a more normal kind to water III, where the thermal agitation more than compensates for the geometrical contraction of the transition from the quartz-like to the close packed structures. According to these authors trihydrol, dihydrol and hydrol have no direct structural analogy to water I, II and III, but the latter explain, by means of the geometrical internal structure of the liquid, physical properties which the former attempted to explain in terms of hypothetical molecules. On the other hand the recent considerations of Bancroft and Gould (1924) are based on the hydrol-dihydrol-trihydrol conception.

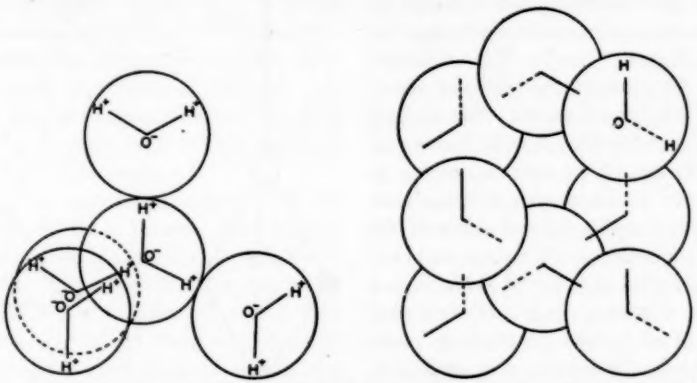


FIG. 2. MOLECULAR STRUCTURE OF WATER PROPOSED BY BERNAL AND FOWLER (1933)

At left the ice-tridymite-like water aggregate present at temperatures below 4°C. At right the quartz-like water form existing in the temperature range 4–200°C. This would be the typical arrangement in biological fluids. The OH directions pointing upwards are shown ———, downwards - - - - - - - -

Bernal and Fowler introduce a new conception of "structural temperature" based on the changes in the structure of water caused by ions, which they believe may prove to be important in many physico-chemical fields, particularly where colloids are involved, and in bio-chemistry. In dilute solutions of strong electrolytes the "structural temperature" is that tem-

perature at which pure water would have effectively the same inner structure as the given solution. The ions loosen or tighten the water molecules depending on their ionic radii and charge. This may explain the antagonistic action of ions such as Ca^{++} and K^{+}, the first lowering, the second raising the structural temperature.

The most recent speculations concerning the molecular structure of ice and liquid water are those of Kinsey and Sponsler (1933) derived from an ice crystal lattice which is new so far as the H ion positions are concerned and is based on the O positions previously determined by W. H. Barnes (1929). The structure provides dihydrol as the polymer occurring in both ice and water. The authors postulate a stable H_3O_2 ion in the crystal and in clusters of dihydrol occurring in liquid water, an assumption which allows a qualitative explanation of many of the abnormal properties of water and ice. Their statement that liquid water is not composed of mono-, di- and tri- hydrol is not supported by the historical evidence (vide supra). However, they appeal to the fact that the only lattice which has been proposed for ice is ionic and does not contain a complex unit of any sort. They attempt to reconcile the ionic picture of ice with the notion of polymers by postulating the alternate spacing (Fig. 3) of an H cation and a complex double pyramidal anion H_3O_2. The whole lattice is a cluster of linear chains of dipole dihydrol units which melt by the destruction of the lattice brought about by a too close approach of the singular H ion (Fig. 3) and the H_3O_2 groups. The result is a liquid which is a mixture of mono- and di- hydrol in temperate equilibrium. In water, clusters of variable size of the two types of molecule are the mobile units. The x-ray diffraction phenomena point to the existence of a kind of orderly clustering which may follow the crystalline arrangement.

Bancroft and Gould (1934) have recently published a splendid paper on the Hofmeister series of anions with specific reference to their effect on the water equilibrium of mono-, di- and tri- hydrol. They point out that liquid water is recognized as being more or less polymerized, but

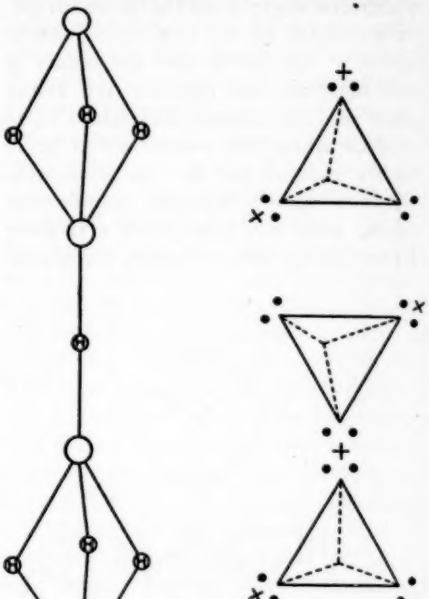


FIG. 3. MOLECULAR STRUCTURE OF WATER

At left the molecular structure of water according to Kinsey and Sponsler (1933) based on the ice lattice of W. H. Barnes (1929). The structure provides dihydrol as the polymer occurring in both ice and water. The pyramidal anion H_3O_2 is alternately spaced with the H ion.

At right the simple water molecule as proposed by Pennycuick (1928) based on the tetrahedral structure of the saturated oxygen atom (the O nucleus with its two helium electrons is omitted). The two H nuclei and the two O lone pairs of electrons are the points of attachment (lower figure) in the formation of chains of water molecules which may close to form a hexahydrol resembling a benzene ring structure (see text).

little use is made of this except to account for the temperature of maximum density of water and for its not boiling at 80–193°K. as calculated by van't Hoff, Walden, Tammann and Sidgwick. In many thermodynamical reasonings the assumption is made tacitly that the degree of polymerization does not change and very few people are interested in the probability of the different forms of liquid water having different properties, yet changes in the structure of water may be very important in such salt solutions as the Hofmeister series. The lyotropic series of chloride, bromide, iodide, etc., is found to hold for true and for colloidal solutions. In true solutions the series holds for reaction velocity experiments (neutral salt effect), electromotive forces, boiling points and displacements of the temperature of maximum density.

The series cannot be entirely due to hydration of ions because the boiling points are more abnormal than the freezing points. Many people have suggested an increased dissociation of water, but no one has maintained it seriously for any length of time. For cases in which one can eliminate adsorption the Hofmeister series is due exclusively to a change in the water equilibrium. When adsorption is selective (as with albumin) a common order is:

$$SCN - I - Br - NO_3 - Cl - SO_4$$

but where adsorption is negligible the series may become:

$$I - SCN - Br - NO_3 - Cl - SO_4$$

The authors make a number of assumptions to explain the shift in the water equilibrium: (1) chloride, bromide, thiocyanate and iodide tend to change dihydrol into monohydrol and have no special effect on trihydrol beyond that which is a necessary consequence of the displacement of the equilibrium between dihydrol and monohydrol. The order of increasing effectiveness is chloride, bromide, thiocyanate and iodide. (2) The nitrate ion tends to convert trihydrol into dihydrol and dihydrol into monohydrol. The amount of monohydrol is less with nitrate ion than with the chloride ion. (3) The sulphate ion tends to convert trihydrol and monohydrol into dihydrol. (4) The electrolytic solution pressure of H is greater in dihydrol than in monohydrol and that of O is less. These assumptions are based in part on the following considerations. Iodides have the highest boiling point and then come thiocyanates, bromides and chlorides. If iodides are the most effective in converting dihydrol into monohydrol then they are more soluble in monohydrol than in dihydrol and are consequently lowering the vapor pressure of the more volatile constituent, therefore the boiling point is abnormally large. Also, iodide lowers the maximum density of H_2O more than bromide and bromide more than chloride. Unfortunately nitrate is more effective than iodide and sulphate more than nitrate. Accordingly the additional assumptions are made that nitrate tends to convert trihydrol into dihydrol and the dihydrol into monohydrol and that sulphate tends to convert trihydrol and monohydrol into dihydrol. The addition of NaCl, NaBr or NaI to a solution of an acid increases the hydrogen ion concentration which necessitates the assumption that the electrolytic solution pressure of hydrogen is greater in dihydrol than in monohydrol (and that of oxygen is less).

In contrast to van Laar (1899) they postulate that alcohol increases the trihydrol concentration since it raises the point of maximum density, and since alcohol will bring back the fluorescence to a too concentrated fluorescent solution, they

consider that trihydrol has a specific effect in promoting fluorescence. Here we see that one of the "closed molecules" of Armstrong may be quite active as the *Spirogyra* and *Euglena* experiments suggest (see below).

Finally the Raman spectrum of water may be considered as a possible indication of the structure of water but it must be remembered that "the effect of the physical state is small in most cases, liquid water, ice and water of crystallization, for example, showing almost the same Raman spectra" (cf. *Nature*, vol. 131, 1933, pp. 263–265). However, Specchia (1930) has examined the Raman spectrum of water at various temperatures (17°, 41°, 80° and 91°) as a possible means for studying changes in the polymerization of water. A slight displacement of the bands was noted, e.g., the maximum 4176 A. U. at 17° is displaced to 4188 A. U. at 91°.

Brunetti and Ollano (1930) studied the Raman spectrum of water as affected by solutes, and they find differences in the intensities of the bands produced by presence of salts. It is interesting to note that the nitrate anion has a contrary effect to that of the chloride anion which may turn out to be a lyotropic effect (cf. Bancroft and Gould, 1934). According to Bernal and Fowler (1933) the Raman spectrum changes in aqueous solutions indicate distortion of the water structure by the solute. Rank (1933) has recently discussed the Raman spectrum of water vapor. According to Rao (1933, 1934) the Raman component in water vapor may be attributed to the single water molecules and the two components of the ice spectrum indicate double and triple molecules (trihydrol). In water at different temperatures all the three components are found with varying relative intensities and from them Rao attempts a calculation of the relative proportion of water molecules (cf. Table 1) at different temperatures. He considers this method more direct than that of Sutherland (1900). He finds a maximum number of double molecules at 4° which perhaps explains the maximum density at this temperature. His percentages of trihydrol at various temperatures agree well with the numerous other determinations (Table 1) but his proportions are somewhat low; for example at 4° he finds only 21 per cent trihydrol as compared to Sutherland's 37.5 per cent.

HEAVY WATER

The problem of the association of water is complicated by the heavy and light hydrogen and oxygen isotopes in the molecule. It is obvious that these two problems can no longer be considered separately. In fact, Bingham and Stevens (1934) find that the extra proton in the nucleus of hydrogen has a profound effect upon the association of water, ***heavy water being inert as a result of its low association.*** Their calculations indicate that deuterium oxide is very much less associated than is ordinary water, the association factor being 1.34 as compared to 2.50 for ordinary water.

The existence of a heavy hydrogen isotope was suggested by Birge and Menzel (1931) and discovered by Urey, Brickwedde, and Murphy (1932). Washburn and Urey (1932) found that the heavy isotope was concentrated in water which had been subjected to electrolysis as in the manufacture of oxygen. Lewis and later Taylor prepared almost pure heavy water by an electrolytic method (cf. Urey's review, 1933). Kendall (1933) asserts that he obtained unpublished evidence of the electrolytic fractionation of water before Washburn, and Thomson (1934) believes that he observed the heavy isotope of H in 1911.

Several résumés of the recent developments in this important field have appeared (*Nature*, 1933, vol. 132, pp. 536–538; and 1934, vol. 133, pp. 197–198; Aston, 1933; Urey, 1933; and Frerichs, 1934) so we shall refer only to the properties of deuterium oxide likely to be of physiological interest.

The terms deuterium for heavy hydrogen and protium for light hydrogen proposed by Urey, Brickwedde and Murphy (1933) (1934) are probably more suitable than subsequently suggested terms such as diplogen of Rutherford (1933), and barhydrogen of Wood (1933) (cf. also Broghton, 1934; Harkins, 1934; and Ficklen, 1934). Sidgwick (1934) defends the term

diplogen which means "making diplon" the nucleus of the heavy hydrogen He points out that deuterium means "second substance" but the second particle after the proton should be the neutron. Fortunately the symbol D for H^2 is widely accepted. The nucleus of D was first regarded as an association of two protons and an electron but the discovery of the neutron and the positron (positive electron) has given alternative possibilities for the nucleus (deuton). According to Sexl (1933) the proton is not a fundamental particle but is a neutron and a positron. Thon (1933) takes the same view and remarks that if the neutron were an aggregate of a proton and an electron hydrogen atoms should be converted spontaneously into neutrons and neutrons should be more numerous. From these considerations the deuterium nucleus may consist of two neutrons, conceived as primary uncharged particles of mass 1, and one position.

The commercial electrolysis of water concentrates the heavier isotope of hydrogen and according to Washburn and Urey (1932) the heavier isotope of oxygen, O^{18}, but the heavy oxygen is not always enriched by further laboratory electrolysis (Selwood and Frost, 1933). The specific gravity of the residual water rises continuously as the electrolysis proceeds, and this is accompanied by a rise in the freezing and boiling points and a decrease in the refractive index. For water of specific gravity 1.0014, the changes are F. P. +0.05°C. and B. P. +0.02° (Washburn, Smith and Frandsen, 1933) and in the concentrated heavy water (cf. Urey, 1933) containing only 0.01 per cent of the normal H the density is 1.1056 at 25° and B. P. 101.42°, freezing point +3.8° and the point of maximum density at about 11.6°. The viscosity is higher and surface tension lower (Table 6). The motility of ions is lower in the pure H^2H^2O (Lewis and Doody, 1933) and the solubility of salts is also lowered (Taylor, Caley and Eyring (1933)), the difference being −7.2 per cent in the case of NaCl. The higher boiling point of the pure heavy water indicates that separation of the isotopic forms can be effected by fractional distillation to a slight extent (Lewis and Cornish, 1933). Uhlmann (1934) reports that old storage batteries contain a slight excess of D.

It is clear that the physical properties of highly concentrated heavy water are of limited biological importance, but the chemical influence of deuterium is extremely significant, especially since an exchange between the normal H in compounds and the heavy H in isotope water and in deuterium gas may take place. Lewis (1933) describes the interchange of isotopes in an aqueous solution according to the following equation:

$$H^1H^2O + NH^1H^1H^1 = H^1H^1O + NH^1H^1H^2$$

in which NH_3 gas is passed into heavy water at 0°C. One mole of water absorbs nearly one mole of NH_3 and since ammonia has 3 H atoms, while water has two, more than half of the H^2 in the system will escape when the ammonia is pumped off. A sample of heavy water having an excess density of 0.000182 was treated in this way and the remaining water had an excess density of 0.000085 or at least 0.000097 of

TABLE 6

Some Properties of Heavy Water (Selwood and Frost, 1933)

	ORDINARY WATER	HEAVY WATER		
		31%	91%	100% (calc.)
Density, d^{t}_{20}	.9982	1.03140	1.0970	1.1056
Viscosity	10.87	11.4	13.7	14.2
Surface tension	72.75	71.5	68.1	67.8 dynes/cm.

Taylor and Selwood (1934) later give the density of 100% D_2O (25°C.) as 1.1079 and the viscosity 12.6.

the original excess density was due to H^2. Another part was treated with sulphur dioxide which removes the excess of O isotope by a corresponding reaction:

$$H_2O^{18} + SO^{16}O^{18} = H_2O^{16} - SO^{16}O^{18}$$

and it appeared that of the original density excess at least 0.000073 was due to O^{18}. Thus heavy water of low concentration from commercial electrolytic cells (which was the first to be tested biologically (T. C. Barnes, 1933a)) contains a relatively large proportion of heavy oxygen which is not enriched by special laboratory concentration of heavy water. This may be important for the interpretation of the favorable biological effect of 0.06 and 0.4 per cent heavy water in contrast to the so-called "lethal" influence of very high concentrations. Webb (1934) states that in heavy water of low concentration used as raw material for concentration processes one half of the excess density is produced by O^{18}. Upon continued electrolysis the oxygen isotope remains constant as shown by the fact that the increased density of discharged water of the apparatus is due to the oxygen isotope only.

Oliphant (1933) reports an exchange between heavy hydrogen gas and normal water over an interval of several weeks and Horiuti and Polanyi (1933) find that the exchange is greatly catalysed by platinum black, possibly due to the ionisation of H corresponding to the electromotive process of the H electrode. They suggest that in the absence of Pt the walls of the vessel may act as a catalyst. It will be of interest to determine what catalytic influences in protoplasm may effect deuterium exchange. Gould and Bleakney (1934) report that the concentration of deuto-hydrogen mixtures in contact with water in a clean glass vessel remains constant. The work of Crist and Dalin (1933) indicates an exchange between water of 1 per cent deuterium concentration and ordinary hydrogen in a quartz tube at 800°C. Bonhoeffer and Rummel (1934) performed the opposite experiment, i.e., they showed that ordinary hydrogen gains weight when exposed to heavy water (with Pt as catalyst).

The exchange reactions are of great biological interest for they offer the possibility of introducing more deuterium into living organisms exposed to heavy water. Pacsu (1933, 1934) finds an instantaneous replacement of the displaceable H in glucose in heavy water but this does not change the value of the specific rotation for the wave length of Na light. According to Halford and Anderson (1934) deuterium is introduced into acetone dissolved in heavy water containing a small amount of potassium carbonate. The effectiveness of an alkaline catalyst argues for a mechanism involving the enol form, and they doubt that in an organic compound not susceptible to such a reaction any replacement of protium by deuterium can be realized by direct contact with water. Lewis and Schutz (1934) show that in deuto-acetic acid the heavy hydrogen is present in the COOH and not in the methyl group. Bonhoeffer and Klar (1934) consider deuterium exchanges in sucrose and sodium acetate. They regard enolization as favorable to hydrogen exchange. Hall, Bowden and Jones (1934) worked with 2 per cent heavy water (which is near the concentration most suitable for physiological experiments) and found (1) no interchange of hydrogen during brief contact, potassium hypophosphite, potassium acetate, sodium benzoate, hydrogen gas, (2) one third of the hydrogen in ethylene glycol immediately exchanged, (3) extent of exchange increasing with time of contact, potassium acetate, hydrogen gas. They state that

the hydrogens of the acetate group are not wholly inert even when nothing is added to promote enolization. In one run, after sixty-six hours of contact, 34 per cent of the hydrogen in the salt had exchanged. It had been previously shown (T. C. Barnes and Larson (1933)) that an incubation period is necessary for deuterium exchange in the enzymes, amylase and zymin in 0.06 per cent heavy water. It is of interest to note that Cavanagh, Horiuti and Polanyi (1934) find that bacteria (*B. coli*) are able, like Pt black, to catalyse the reaction:

$$HD + H_2O = H_2 + HDO$$

when the partially heavy hydrogen is shaken in a sealed reaction vessel with a de-aerated saline suspension of bacteria.

According to Lewis and Schutz (1934b) the large difference in vapor pressure between hydro- and deuto- forms of such substances as water and NH_3 is almost entirely due to the greater strength of the D bond as compared to the H bond. The same authors (1934c) describe the alteration in the properties of substances having H replaced by D, i.e., the ionization constant of deutoacetic acid is less than one third that of acetic acid in common water. This enormous shift in equilibrium shows how much more tenaciously a deuton is held by a pair of electrons of another atom than is a proton. The ionization of an organic acid involves the separation of H + or D+ from a pair of electrons of a carboxyl oxygen.

The biological experiments with heavy water are developing so rapidly at the present time that it is impossible to present an adequate summary. Lewis (1933c, 1934) found that tobacco seeds failed to germinate in nearly "pure" H^2_2O and developed at half the normal rate in 50 per cent H^2_2O although the seedlings appeared normal after a month's time. Seeds which had remained three weeks in "pure" H^2_2O showed some germination when transferred to normal water but the sprouts were thin and soon died. Lewis suggests that when the heavy water first began to permeate the seeds, it was diluted by the "bound" water already in the seeds and produced a medium in which germination could begin but that as soon as the total water within the seed reached a high concentration in heavy hydrogen, the process of germination was stopped. Lewis also reported preliminary experiments indicating that pure heavy water may remain bacteriologically sterile. *Planaria* in 90 per cent H^2_2O for four hours showed a 50 per cent mortality. A mouse was given 0.66 gr. of D_2O which would be the equivalent of the consumption of 4 to 5 litres of heavy water by a human being. The mouse survived and seemed normal the next day but during the experiment "he showed marked signs of intoxication. While the control mice spent their time eating and sleeping, he did neither, but became very active, running and leaping about. . . . . The more he drank of the heavy water, the thirstier he became." Taylor, Swingle, Eyring and Frost (1933a and b) state that 92 per cent heavy water will not support *Rana clamitans* tadpoles, *Lebistes*, *Paramecium* and *Planaria* but they report that 30 per cent concentration has "no effect" over a period of three days. However, they referred to an obvious toxic action rather than the modification of a normal physiological process.

These experiments with highly concentrated deuterium oxide throw little light on the physiological significance of the heavy hydrogen isotope but are valuable contributions to what Just (1930) has aptly termed "the literature of cellular death." Results with heavy water containing a deuterium content slightly above that in ordinary water were secured by

one of us (T. C. Barnes, 1933a) in May, 1933, prior to the work on pure D_2O. These experiments with 0.06 per cent heavy water of density 1.00006 (kindly determined by Dr. E. Ball, 1933) were designed to show the isotope effect under conditions approaching the state of undisturbed living matter in the sense of Crozier. All ordinary water contains a small amount of deuterium, the estimates of the naturally occurring proportion of heavy hydrogen running from 1 part in 4,500 (Birge and Menzel, 1931) to about 1:30,000 (cf. Aston, 1933) but the determinations of Bleakney and Gould (1933) and Lewis and Macdonald (1933), i.e., 1:5,000 and 1:6,500 respectively are perhaps most widely accepted (confirmed by Taylor and Selwood, 1934). The latter results would indicate that the isotope water employed in the *Spirogyra* experiments (cf. T. C. Barnes, 1933a) contained two to three times the deuterium of the controls.

Goldsmith (1934) shows that the disintegration of D in stars leads to an abnormally low D:H ratio in stellar atmospheres, i.e. 1:600,000.

There is evidence of a slight variation in isotopic composition in nature (besides that of the radio active elements). Thus water from the Dead Sea is 2.1 ± 0.5 parts per million heavier than ordinary water, Great Salt Lake water 2.7 ± 0.7 heavier, and water from Rasorite (native borax tetrahydrate) is 6.9 ± 10.3 heavier (cf. *U. S. Bureau of Standards, Technical News Bulletin*, No. 196, p. 81, 1933). Some methods, perhaps of insufficient sensitivity, do not show the greater density of Dead Sea water (cf. Clark and Warren, (1934)). Evaporation from brine apparently concentrates deuterium. Tucholski (1934) regards very slow evaporation (mountain caves) as a more efficient concentrating agent (but cf. Hughes Ingold and Wilson (1934)). Sea water is heavier by two parts per million than fresh water (Gilfillan, 1934). This difference is possibly a result of natural distillation. From the work of Washburn, Smith and Frandsen (1933) Gilfillan calculates that water vapor contains 2.8 per cent less deuterium than liquid water with which it is in equilibrium. Assuming the natural abundance of D to be 1:5000, he calculates that the first distillate from a large amount of water should be lighter by 0.3 ppm. due to differences in D. Using an abundance figure of 1:630 for O^{18} he considers the total concentration effect to be 5 ppm. On the basis of the Boltzmann distribution theorem, it can be shown that, *if* in the deeper parts of the ocean statistical equilibrium has been reached, pure water from a depth of 4,500 m should be heavier by a maximum of 7 ppm. than water from the surface. This would indicate separation of isotopes by the gravitational field but Gilfillan found the astonishing result that surface sea water has the same density as a sample from a depth of 4,500 m, indicating that the sea has not reached statistical equilibrium (cf. also Ball, 1933). The *polymer* difference would, of course, disappear when the pressures were equalized. There is a slight physiological concentration of deuterium in plants, willow sap containing water with 2.9 parts per million more deuterium than ordinary water (Washburn and Smith, 1934), (Smith, 1934). According to Dole (1934a and b) there is no natural separation of isotopes for the excess density found in organic samples is due to the O^{18} in the O_2 used to burn the compound or to the concentration of D produced by *condensation* of the derived water. Thus careful determinations show that benzene, kerosene and cholesterol from spinal fluid have a normal D content. But Snow and Johnston (1934) believe that the excess

density of natural butane is not entirely due to the O^{18} in the tank oxygen used in the determination. Stewart and Holcomb (1934) find no difference in the density of water distilled from milk and urine of the same cow and tap water but their method may not have been sufficiently delicate.

The first experiments with dilute heavy water (Barnes, 1933a) showed that mass cultures of *Spirogyra* exhibited much less abscission or cell disjunction and greater longevity in 0.06 per cent deuterium water as compared with ordinary water. According to Lloyd (1926) excessive cell disjunction is a reaction to unfavorable conditions. That this low concentration of the isotope may be significant was further demonstrated (T. C. Barnes and Larson, 1933, 1934) in experiments confirming the longevity effect in *Spirogyra* determined by cell counts and demonstrating the decreased activity of amylase and zymin incubated in the heavy water. The abscission effect is seen only in long filaments of *Spirogyra* and not in the short lengths (5 to 50 cells) isolated for quantitative study in small Petri dishes containing 5 cc. of water samples. Of a total of 16 filament sections containing 355 cells in isotope water, the average cell life was 6 days while in ordinary water a total of 15 filaments containing 322 cells showed an average cell life of only 3 days. *Spirogyra* is particularly suitable for water experiments on account of its high water content, photosynthetic activity, dependence on turgor pressure and filamentous form which permits daily measurements of the same cell. With *S. nitida* immediately after division the cell measures about 200μ and divides again after the typical length of about 390μ is attained although cells may elongate to 475μ or more before dividing. It is significant to note (T. C. Barnes and Larson, 1934) that the greater longevity in isotope water was observed in all cases despite the wide variation in average cell length. Moore's solution in various concentrations was added to the water samples to eliminate a possible salt impurity, and CO_2 and O_2 were bubbled through the water to rule out an effect due to a difference in gas content. The slightly concentrated heavy water appeared to have little or no effect on the rate of cell division or on the rate of elongation of the cells (we avoid the ambiguous and abstract term "growth"), but had a profound influence on the length of life of the cells in the hypotonic solutions employed. More cell division occurred in the heavy water because the filaments lived longer in it. Increased cell division was observed in *Euglena* kept for forty-five days in 0.06 per cent heavy water (T. C. Barnes, 1934a). The initial population at the beginning, 31,750 cells per cc. increased to an average of 51,112 cells in ordinary water and 59,087 cells in the heavy water. There were 1,900 moving forms per cc. in the ordinary water and 4,400 in the "heavier" water (averages). The cells in ordinary water tended to be clumped together in small groups.

The dilute heavy water had a marked effect on enzyme action—the digestion of starch by pancreatic amylase and the fermentation of glucose by zymin. The retardation of the hydrolyses was obtained when the enzymes had been exposed for a time to the isotope water. With this low concentration, however, there is no apparent difference in reaction rate between the enzyme solutions in isotope water and distilled water controls if the enzyme is not incubated nor when the substrate is incubated in place of the enzyme. The total difference in reactivity between the heavy and light water solutions (10–15 per cent more CO_2 production in the latter) (Fig. 4) was nearly the same

when the zymin was treated for 16 hours or 166 hours, indicating a stoichiometric exchange of H. The progress of digestion of starch by pancreatin was followed by removing alternately five drop samples of the solutions to spot plate depressions and adding a drop of dilute iodine. The erythrodextrin stage was reached in 6 minutes in the controls and 8 minutes in the solutions containing amylase which had been incubated in isotope water for 24 hours.

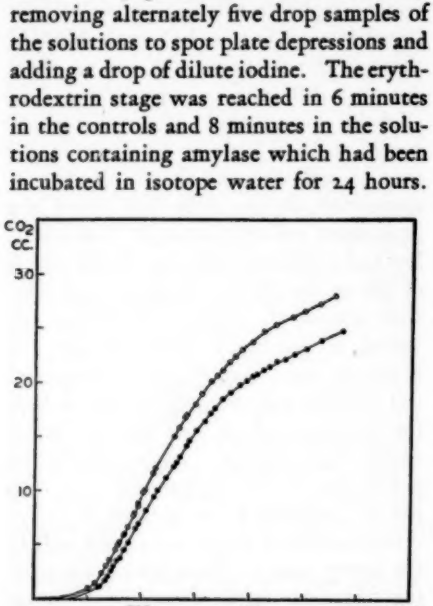


FIG. 4. THE INFLUENCE OF THE HEAVY HYDROGEN ISOTOPE ON ENZYME ACTION (AS DETERMINED BY MR. E. J. LARSON)

The decreased CO_2 production (dark circles) in fermentation by zymin which has been incubated in heavy water of .06 per cent deuterium is compared with the CO_2 production by zymin which has been exposed to ordinary water (open circles) (cf. T. C. Barnes and Larson, 1933). Since the incubation of the substrate (glucose) in heavy water does not produce the reduced activity, Larson's theory postulates the introduction of deuterium in a key position in the enzyme.

After the effect on *Spirogyra* was obtained, our colleague Dr. Oscar Richards kindly consented to repeat the tests with yeast (cf. Richards, 1933) and confirmed our discovery that a slight excess of deuterium in water may be biologically significant. He observed a 26 per cent increase in dry weight of yeast grown in our isotope water, and Meyer (1934) found the same effect in *Aspergillus*. Taylor and Harvey (1934) later measured the O_2 consumption of yeast in heavy water but were unable to interpret their results (cf. below).

The regeneration of the flatworm *Phagocata gracilis* was tested in the 0.06 per cent isotope water but no macroscopical difference was observed (T. C. Barnes and Larson, 1934). However, the animals were left in the water and after a few months time a striking difference was observed which became slowly more evident—the worms in the light water gradually shrank to one-fifth or less of their original body size while in the isotope water only a slight diminution was seen. A large excess of water was present (50 cc.) containing one drop of Ringer per 10 cc. It is possible that the longevity of *Spirogyra* and the inhibition of shrinkage in the starving planarians are due to retarded enzyme hydrolysis as the amylase experiments suggest.

The body size experiments on *Planaria* were repeated in slightly more concentrated heavy water (0.47 per cent or 1 part deuterium to 213 parts protium) and a new effect appeared (Larson and T. C. Barnes, 1934). The animals in heavy water of this concentration were parasitised by moulds and succumbed within three weeks. In some cases the living animal becomes invested with slime mould and in others is covered with tufts of mycelium. It would appear from the work of Meyer on *Aspergillus* and our *Planaria* experiments that heavy water having a 1:200 deuterium ratio may have a specific effect in stimulating the growth of moulds and possibly bacteria. This property should afford many interesting problems in parasitology and might be of considerable importance in the possible therapeutic use of heavy water of low concentration. Klar (1934) objects that

moulds in our experiments were stimulated by paraffin impurities but he is not clear in explaining how a trace of organic matter could influence moulds grown with added nutrients (cf. Meyer 1934; Richards 1933).

Von Hevesy and Hofer (1934) used heavy water of about this composition, 0.5 per cent in their work with goldfish. They found that the rate of exchange of heavy water of this strength was the same as that of normal water but the experiments lasted only a few hours and no quantitative studies of metabolism etc. were made.

Our zymin effect explains the subsequent work of Pacsu (1934) who observed that fermentation by yeast cells in nearly pure H^2_2O was nine times slower than in ordinary water, but he did not attempt to limit the effect to the enzyme. The results are in harmony with the increased dry weight found in yeast grown in isotope water by Richards (1933). On the other hand Macht and Davis (1934) report that fermentation experiments with yeast and 4 per cent cane sugar in ordinary and 0.06 per cent deuterium water showed no difference. This we think was due to the fact that the zymase was not incubated in the heavy water prior to the test which we showed to be necessary with very low concentrations of heavy hydrogen. These authors found a slight inhibitory effect on germination of *Lupinus* seedlings but no apparent results with mammalian tissues (contraction of intestinal loops, etc.).

However, Meyer (1934) working with dilute isotope water (1 part in 213) confirmed our original view that a slight excess of deuterium may be biologically significant. He found that the dry weight of *Aspergillus* mats in the heavy water was 16 times that of the felts grown in ordinary distilled water (plus nutrients in each case) and that the fruiting was "greatly diminished." These results resemble our previous experiments (Barnes and Larson, 1934) showing a greater spreading of *Oscillatoria* in unbuffered isotope water of 0.06 per cent concentration.

Brief mention must also be made of recent sporadic tests of heavy water which require re-interpretation. Sugiura and Chesley (1934) announce that the proliferating capacity of the mouse sarcoma 180 and mouse melanoma is unaffected by 14.8 per cent and 40 per cent heavy water when isotonic. They place the tissue in heavy water for 12–24 hours at 4–5°C. at which temperature the chemical reactions of growth favorable for exchange of isotopes are inhibited. The tissue is then *removed from heavy water* and transplanted into a normal animal where of course it grows at the higher temperature. No quantitative data are given relative to the growth rate which, moreover, is not measured in an environment rich in D. There is no previous evidence for a "lethal" action of heavy water of the concentrations used by these authors who overlook the time factor necessary for the slow influence of deuterium. They find a 156 per cent increase in weight in tumor tissue swelling in 14.8 per cent heavy water as compared to 130 per cent in ordinary water which they do not regard as a deuterium effect but one depending on a difference in pH of the isotope water, being apparently unaware that it had been shown previously (T. C. Barnes and Larson, 1933) that isotope water has a higher pH which may depend on the deuterium content (lower mobility of D or change in dissociation constant of dissolved substances). Harvey and Taylor (1934a) set out to find the cause of the "deleterious effect of heavy water for living things" following Lewis in the use of high concentrations of deuterium. They fail to realize that 100 per cent heavy water represents a five thousand fold increase in a normal constituent of protoplasm. This

old fashioned physiology of subjecting organisms to the most extreme conditions possible is fortunately yielding place to a more careful study of the organism as undisturbed living matter in which slight increases in constituents may reveal their rôle in the normal animal. Taylor and Harvey find as Lewis did that 86 per cent heavy water has a depressing action, in this case on the oxygen consumption of bacteria. It is obvious, however, from their Fig. 1 representing the O_2 consumption of marine bacteria that their "control" of 0.18 per cent D_2O has a higher rate than the ordinary water experiment, confirming our results that dilute heavy water may have a stimulating action. These authors, however, ignore previous work and do not realize the significance of the slight increase in O_2 consumption in 0.18 per cent D_2O (which probably would have been more significant if a longer time interval had been used and the number of bacteria counted). In their study of the O_2 consumption of yeast (Taylor and Harvey, 1934b) these workers again find that there is more O_2 consumed in 0.18 per cent D_2O than in ordinary water but fail to realize the significance of this result (seen clearly in their Fig. 1). It would be interesting to compare their results with the slightly reduced activity of zymin (Barnes and Larson, 1933) and the increased dry weight of yeast (Richards, 1933) in dilute heavy water but they do not have any measurement of the quantity of yeast at the end of the experiment.

Hackh and Westling (1934) suggest that accumulation of heavy water by evaporation in the human body may cause senility, being apparently unaware that the first biological experiments showed that a low concentration of D_2O increases longevity of cells.

Although the nature of the action of the heavy isotope on protoplasmic activities must remain conjectural until more work is completed, it is evident that a number of possibilities may be considered. (1) Lewis (1933c) suggests that the "selective power of living organisms may segregate the isotopes in some of the substances necessary to growth." He originally considered heavy water as "lethal" to living organisms, but later (1934) he writes "heavy water is never toxic to any high degree and it is tolerated in high concentrations by lower organisms." He suggests that the rate of vital processes seems to be roughly proportional to the fraction of total hydrogen which is H^1. However, in this connection it should be remembered that a very slight concentration of isotope may have a relatively enormous effect, probably due to its influence on a key reaction. (2) It is also possible (T. C. Barnes, 1933) that an explanation may involve bound water in colloids which is known to be of greater density than "free" water. This might exert a stabilizing effect. Moreover, Washburn and Smith (1933) have shown that heavy water molecules are preferentially adsorbed on charcoal from deuterium water of approximately the same concentration as used in the *Spirogyra* and enzyme experiments. Woodward and Chesley (1934) report that gelatin absorbs 20 per cent less of 90 per cent heavy water in a given time than it does ordinary water. (3) The heavy water effects may be conditioned by a pH difference (T. C. Barnes, 1933) especially since Bernal and Fowler (1933) have calculated that the heavy isotope has only one-fifth the mobility of the light (cf. also Lewis and Doody, 1933). A slightly higher pH in heavy water of 0.06 per cent and 0.5 per cent concentration was found (Barnes, 1933) which may be a direct result of the lower H activity or its influence on the dissociation of dissolved substances. The

inhibition of abscission in *Spirogyra* is seen in buffered heavy water but not the increased spreading of *Oscillatoria*. However, the digestion of starch proceeds more slowly in heavy water in spite of the fact that the latter is nearer the optimum pH (T. C. Barnes and Larson, 1933). (4) The biological results may be entirely traced to the influence of deuterium on enzyme action (T. C. Barnes and Larson, 1933, 1934). The work with amylase and zymin suggests an exchange between the excess deuterium in some key position of the enzyme molecule which was first proposed by our colleague Mr. E. J. Larson. Perhaps there is an exchange of the amino group or peptide binding in the enzyme. Eyring and Sherman (1933) reporting the general chemical activity of the heavy isotope, apart from enzymes, states, "All chemical reactions having a positive temperature coefficient go about half as fast or less at ordinary temperatures with the heavy as with the light H. It will be possible to single out such reactions in biological processes." (5) Bioelectrical potentials may be changed by a suppression of ionization brought about by the presence of the heavy isotope. (6) Bingham and Stevens (1934) state that heavy water is inert due to low association (reduced trihydrol content), which would apply principally to the concentrated deuterium oxide which has a low association factor. This may prove to be a line of contact between the ice water and heavy water experiments. Cabrera and Fahlenbrach (1934) are probably mistaken in their suggestion that concentrated heavy water is more strongly polymerized than H_2O. They did not determine the association factor but found that the difference in the diamagnetic susceptibility of D_2O is less than that of H_2O at the melting point. Another possible connection may be through the work of Uhlmann (1934) who is investigating a possible concentration of H^2 during sublimation (evaporation) of ice and snow. This might help to explain the activity of organisms in melted ice water in the spring. (7) A small concentration of deuterium oxide may be an essential constituent of protoplasm. For example, Ca may be quite essential in small amounts quite apart from its action on a living organism in a saturated solution.

Whatever the explanation of the biological effect of heavy water may be, it is clear that physiology is greatly indebted to Washburn and Urey for their discovery of D_2O.

A third isotope of H of mass three, tritium (T), was announced by Latimer and Young in 1933 (*Phys. Rev.*, 44: 690) and was found to result from the collisions between deutons of high energy by Oliphant, Harteck and Rutherford (1934). Tuve, Hafstad and Dahl (1934) find H^3 (T) in concentrated deuterium samples and Lozier, Smith and Bleakney (1934) report an abundance ratio T:D = $5:10^6$ in pure heavy hydrogen. This means that the ratio T:H in natural hydrogen is probably of the order $1:10^9$ and has not yet become physiologically significant. However, Hornwell, Smyth and Van Voorhis (1934) have concentrated the third hydrogen from the natural 1 part in 200,000 in pure deuterium to 1 part in 5,000 D which suggests that tritium may ultimately be obtained in biologically significant concentrations.

BOUND WATER

We do not propose to review the problem of "bound" water in colloids and living tissues for nothing is known about the possible effect of polymerization on the degree of bound water. Gortner (1930) believes that an appreciable fraction of water in organisms is not "free," as

judged by the fact that only part of it freezes even at very low temperatures; but Hill (1931) finds little evidence for bound water as measured by vapor tension which, however, is not always a direct indicator of the state of water (for example, ice evaporates as a polymeric vapor). Greenberg and Greenberg (1933) also conclude that practically all the water in colloidal solutions is free as judged by its ability to dissolve urea and glucose. Since bound water is more dense (cf. Barron, 1931) than free water, it is not composed of the bulky "trihydrol" aggregates, but it is interesting to note that according to Marinesco (1930) the dielectric constant of "bound" water in tissues appears to be the same as that of Ice No. VI, which is known to exist only under enormous pressures. It would appear that although some bound water is present in the living cell, there is enough free water to permit the existence of trihydrol molecules. The rapid spreading of feathery ice crystals in *Amoeba* protoplasm at −0.8°C. (Chambers and Hale, 1932) supports the view that there is a large proportion of "free" water. Kedrowsky (1931) regards the free water as that which is available for chemical transformations without changing the plasma colloid structure. It must be remembered that the free-bound water equilibrium is not a static one (Spek, 1928). Gortner and Gortner (1934) have recently defended the bound water concept and they conclude that the bound water values as determined by the cryoscopic method parallel the physiological responses of plants to environmental conditions. Bull (1934) successfully meets the criticisms of Grollman (1931), for the negative amounts of bound water found by the latter are due to the fact that the KCl used in Grollman's method is adsorbed by the colloids along with the water. A direct line of contact between the bound water problem and the structure of water discussed in this review is afforded by the results of Kolkmeijer and Favejee (1933), showing that many of the x-ray lines from emulsoid sols at ordinary temperatures correspond to ice lines. Of 21 lines on a starch picture, 15 correspond to the first 15 of a possible total of 18 ice lines. The inference is that the bound water is oriented on the surface of the particles in the ice lattice. It is probable, however, that the water molecules in the bound state are not the same as the trihydrol aggregates, because the latter have a lowered density. The hypothesis may be considered that the bound water is composed of trihydrol molecules whose density has been increased by pressure, and this is in agreement with the findings of Marinesco (1930).

VAPOR PRESSURE

It is obvious from the above historical survey of the polymerization of water that further investigation is needed in this important field. It is hoped that our work on the biological effect of "ice-" and "steam water" will stimulate more extensive research on the properties of water, even if this proves fatal to our present working hypothesis that trihydrol aggregates play an essential rôle in certain types of living cells. In this connection one may mention the recent experiments of Menzies (1932), who compared the vapor pressure of 10 cc. samples of recently boiled and frozen distilled water at the same temperature. The apparatus consisted of two 25 cc. Pyrex bulbs connected by a water manometer. Under these conditions Menzies found no appreciable difference in vapor pressure. It is doubtful, however, if vapor pressure is a direct indicator of the concentration of water polymers. In fact, it is the only important property of water which previous investigators have not studied in relation

to association. The vapor tension of ice and of water is treated in *Ice Engineering* by H. T. Barnes (1928, pp. 31–33, 56–67). Barnes and Vipond in 1909 found the surprising result that the heat of vaporization of ice at 0°C. is almost identical with that of water at 0°C., which indicates that ice evaporates as a polymeric vapor. In ordinary evaporization of ice the change of the solid vapor to ordinary vapor takes place just outside the surface and would escape detection in the usual vapor pressure measurements.

As was mentioned above, Baker (1927) used vapor pressure as a criterion for association changes but his work was criticized by West and Menzies (1929) and Wright and Menzies (1930).

Little is known concerning trihydrol in the air but it acts as nuclei for the formation of rain drops, fog and hoar frost and the presence of ice particles in the upper atmosphere is shown in the phenomenon of sun dogs and moon dogs (H. T. Barnes, 1928, p. 10).

RATE OF FREEZING

Inasmuch as ice exhibits anomalies in its mode of evaporation it is suggested that other methods than those involving vapor tension might yield more direct indication of the concentration of liquid ice in water. Judging from the discrepancies in the papers reviewed above it appears that we have at present no means of determining the precise degree of association and concentration of water polymers, but it seems reasonable to infer that "ice water" will contain more trihydrol for a limited time at least than "steam water" immediately on condensation. On the colloidal theory of water, ice forms when the trihydrol concentration reaches the saturation point, so it occurred to one of us (T. C. B.) that it would be of interest to determine the *time* required for equal samples of "steam-" and "ice water" to freeze at the same temperature. It was found that to cc. of fresh ice water, warmed rapidly to 10°, would freeze three times as rapidly as condensed steam water cooled rapidly to 10°; both samples, of course, being subjected to the same freezing temperature. On the basis of the colloidal theory these results might be interpreted on the grounds that, since ice forms when the dihydrol is saturated with trihydrol, water containing more liquid ice aggregates would take a shorter time to freeze than condensed steam water containing less trihydrol. However, *great caution* must be exercised in interpreting new experiments of this nature, but they seem to give tentative support to our hypothesis. The ice was obtained from absolutely clear portions of large blocks of commercial ice. This ice when perfectly clear yields water of great purity. H. T. Barnes (1928, p. 59) states "my own tests on water from melted ice show it to be so closely allied to the purest distilled water that it is indistinguishable by a chemical examination. Provided ice is clear from air pockets it may be safely used, even when frozen from a polluted source." In the manufacture of artificial ice there is an opaque core into which all the foreign matter from the water has been thrust. An ice crystal cannot form unless it is absolutely devoid of foreign material. In a recent study of the crystal structure of ice W. H. Barnes (1929, p. 676, see also fig. 3) states "all attempts to grow single crystals of ice with well developed faces failed. Only needles could be obtained. The crystals finally employed . . . . were found in commercial, artificially frozen ice. . . ." Indeed, Zsigmondy (1920) recommends melted ice water as the purest water obtainable for ultra-microscopical work. Frozen steam water was used in some of

the *Spirogyra* experiments, but as Plyler (1924) states, it is difficult to freeze small quantities of distilled water to obtain ice with large crystals and free from bubbles. The crystals grow slowly with aging, as indicated by Plyler's photograph of commercial ice kept for several months. The lines of separation between the large crystals stand out on melting, a fact which we have also observed in our own samples. This hard, clear "large crystal" ice seems to yield water of greater sustaining action for *Spirogyra* than that from bubbly fine crystalled ice obtained by the rapid freezing of small quantities of steam water. It is suggested that this latter type of ice does not yield as rich a solution of trihydrol. However, ice water from frozen steam water freezes more rapidly than steam water cooled rapidly to the same temperature, but we have not yet prepared freezing time curves for this type of ice water.

The original freezing time curve was obtained by placing samples of water from "large crystal" clear commercial ice and condensed steam water in test tubes in a wooden rack outside in December, 1932 (fig. 5). This simulated natural conditions and also afforded greater visibility than is possible when the tubes are surrounded by brine mixture in a pail or in Dewar flasks.

In collaboration with Professor F. E. Lloyd, freezing experiments were carried out at McGill University in December, 1932, to test water prepared under the same conditions as those obtaining in the *Spiro-*

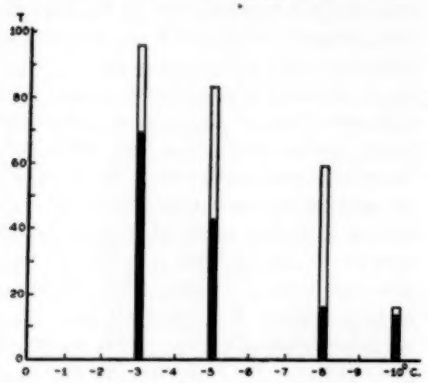


FIG. 5

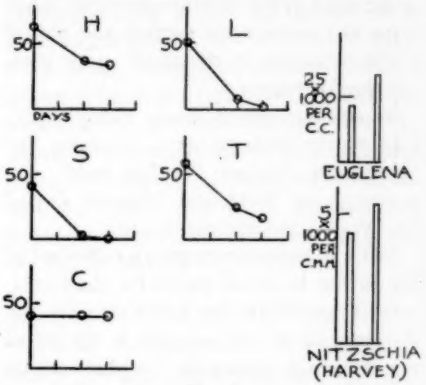


FIG. 6

FIG. 5. FREEZING TIME CURVE FOR 10 CC. SAMPLES OF ICE WATER AND STEAM WATER BOTH BROUGHT RAPIDLY TO 10°C.

Abscissae: temperature of air in degrees below zero C. Ordinates: time in minutes required for freezing Black columns: ice water. Unshaded columns: steam water. The test tubes were placed outside in a test tube rack during cold weather in December, 1932. Under these conditions the water freezes more slowly and the end point (sudden appearance of feathery crystals throughout the sample) was more readily seen than when the tubes are immersed in a brine freezing mixture.

FIG. 6. THE EFFECTS OF VARIOUS KINDS OF WATER ON SPIROGYRA, EUGLENA AND NITZSCHIA

The *Spirogyra* graphs (H, L, S, T, C) represent the number of living cells in short sections (50 cells) of the same filament in heavy water, H, of low concentration (.06 per cent deuterium); in ordinary light water, L; in steam water renewed twice daily, S; in ice water, which on our theory contains more trihydrol, T; and in the control, C, in pond water (cf. T. C. Barnes and Larson, 1933). Abscissae: time in days; ordinates: number of living cells. The *Euglena* chart shows the relative population in condensed steam water (left) and ice water (right) after two weeks (T. C. Barnes and Jahn, 1933). The *Nitzschia* chart shows the increased population (right) in sea water to which ice water has been added (Harvey, 1933.) (See text.)

gyra experiments of 1931 (Lloyd and Barnes, 1932). It was found that the water from the same quartz still did not freeze as rapidly as water from clear river ice, thus supporting the New Haven freezing experiments.

PHYSIOLOGICAL EFFECTS OF ICE WATER

Experiments concerning the effect of ice and steam water on *Euglena* have been described briefly (Barnes and Jahn, 1933) and the present paper presents a more detailed description of these experiments. The stock cultures of *Euglena gracilis* were grown under bacteriologically sterile conditions in a medium of inorganic salts and hydrolyzed casein (Jahn, 1931), and also in the same salt solution under non-sterile conditions. In each experiment a large number of *Euglena* was taken from one type of culture and washed several times by centrifuging with water which had been distilled several weeks previously. The washed cells were then divided equally into two containers and fresh ice water was added to one-half while the same amount of fresh steam water was added to the other half. The steam water was prepared from a Pyrex still and the ice water was obtained from commercial block ice, the purity of which has been discussed previously (Lloyd and Barnes, 1932, and elsewhere in the present paper). Both kinds of water were at approximately the same temperature (10°–15°) when poured on the organisms. Since *Euglena gracilis* grows well at a temperature as high as 30°C. and the narrowest recorded range of non-lethal temperatures for the species is 0–37.5° (Jahn, 1933), any lethal effect could not be ascribed to these temperature differences. The initial concentration of organisms (in thousands per cc.) was determined (method described by Jahn, 1929), and the organisms were placed in centrifuge tubes and kept at approximately 10°C. Under these conditions any slight difference in temperature between the types of water would rapidly disappear. Three tubes of organisms in each kind of water were used for each experiment; therefore, each experiment was in triplicate.

In seven of the eight experiments the water was changed daily by centrifuging; in the eighth it was changed twice a day, and in this last experiment samples of the water used were subjected to the freezing tests described below. The tubes were well shaken to redistribute the organisms throughout the tube after centrifuging, and this shaking also tended to equalize the gas tensions of the water. The tubes of experiments IV and VI were placed in an ice chest containing a 25-watt light globe, 15 inches from the cultures. The temperature of these cultures was approximately 10°. The tubes of the other experiments were placed near a closed north window, and the temperature of these cultures was 10–15°C. The results of the eight experiments are shown in Table 7. Each concentration given is the average of the count taken on two samples from each of the triplicate tubes. No one count differed by more than 15 per cent from the mean of the six counts.

The data show that in seven of the eight experiments a relatively larger amount of growth occurred in the ice water. The average increase in concentration of organisms in the steam water was 32 per cent (16.4 compared to 21.7 thousand per cc.), whereas the increase in the ice water was 105 per cent (16.4 to 33.6 thousand per cc.). Cells in the ice water of all experiments except experiment VII were, on the whole, much more motile than those in the steam water, and after the first few days there was an increasing tendency of the organisms in the steam water cultures to remain in the bottom of the tube. The

ice water cultures also showed this tendency to a certain extent, but it always occurred first and was more pronounced in the steam water. Also, in the steam water there was apparently a much larger percentage of dead cells at the end of the experiment. Dead cells do not disintegrate immediately under the conditions of the experiment but remain in the water for at least two weeks, during which time they slowly become decolorized. Since it is quite impossible to tell by observation the percentage of green euglenas which are dead, figures for these percentages are not available. The motility effect was reversed in experiment VII, the steam water cultures showing a greater motility as well as a greater increase in number. In this experiment the results are directly contradictory to those of the other seven experiments, and as yet we have no proven explanation for the results. It does not seem to have been caused by an experimental error, and an explanation of this contradiction might involve factors which would also account for previous contradictory results obtained on the effect of various substances on *Euglena gracilis* (Zumstein, 1900; Ternetz, 1912; Pringsheim, 1912; Mainx, 1928; Jahn, unpublished observations). Certain sugars sometimes produce a large acceleration of growth, while at other times these same sugars produce a deceleration and encystment. Jahn (in a forthcoming publication) has obtained both types of results under the same conditions of light and temperature and by using media tubed from the same solutions at the same time. These contradictions are believed to be caused by the metabolic condition of the cell at the time the experiment is started, and there is considerable cytological evidence concerning reserve materials which would make this theory seem plausible, but as yet it has not been proven.

TABLE 7

The Effect of Pure Ice Water and Pure Stream Water upon the Growth of Euglena gracilis. The Water was Changed Daily in all Cases Except in Experiment VIII in Which it Was Changed Twice Daily. For Further Explanation See Text

EXP.	PREVIOUS MEDIUM	INITIAL CONC.	DURATION OF EXP.	FINAL CONC.		RATIO OF FINAL CONCS. (ICE WATER) / (STEAM WATER)
				Steam water	Ice water	
			days			
I	Peptone	15	15	18	40	2.2
II	Peptone	16	10	22	36	1.6
III	Peptone	18	14	21	36	1.7
IV	Peptone	15	14	20	35	1.7
V	Salts	17	13	20	30	1.5
VI	Salts	15	14	20	26	1.3
VII	Peptone	10	10	20	13	.6
VIII	Peptone	25	16	33	52	1.6
Total.....		131		174	268	1.54
Average.....		16.4		21.7	33.4	1.54

The effect of low concentrations of salts in the ice water and steam water was investigated in unpublished experiments by T. C. Barnes and M. Glass on *Spirogyra nitida*. To the water prepared as above was added 2 per cent concentrated Moore's

solution, an amount which should suppress any difference in the traces of ordinary salts in the two types of water. Large, healthy filaments of *S. nitida* were placed singly in the two solutions. These solutions were renewed daily, and at the end of four days the number of colorless and shrunken and the number of normal cells were counted. In a typical filament, out of 112 cells in the steam water, only 25 (22.3 per cent) were normal; out of 65 cells in the ice water, 54 (80.6 per cent) were normal. It is concluded that any effect due to traces of common salts (present in Moore's solution) coming from the ice would be ruled out.

The present experiments on *Euglena*, as well as the earlier work on *Spirogyra* (T. C. Barnes, 1932; Lloyd and T. C. Barnes, 1932) show that ice water and steam water appear to have decidedly different physiological effects on these organisms. The curves of Wills and Boeker (1932) show a very striking hysteresis effect in the same temperature range as used in these experiments, and, according to their data, at least five hours is required for adjustment of polymer equilibrium; therefore, one is led to believe that the present effect may be due to the ratio of the water polymers. Since our two types of water had recently undergone a change of state one might expect that the time for readjustment of the polymer ratio should be longer than five hours. How the observed physiological effect is brought about is not known, but the results obtained so far are not incompatible with the original working hypothesis that trihydrol particles influence certain types of cells.

In connection with the *Euglena* work, freezing time experiments were also made

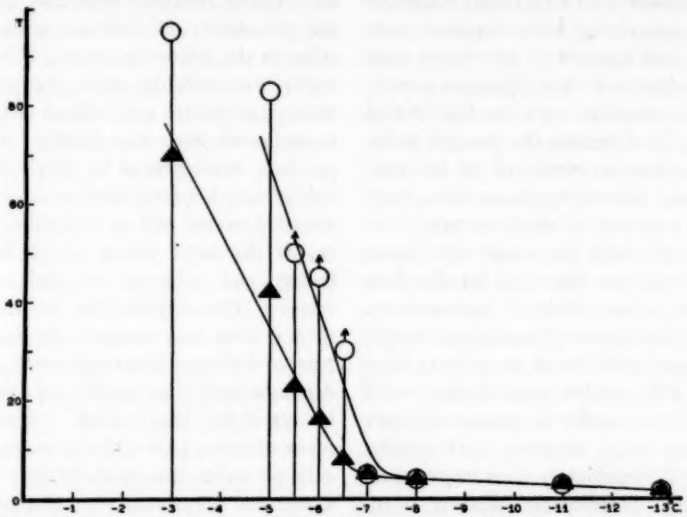


FIG. 7. FREEZING TIME CURVE FOR 10 CC. SAMPLES OF ICE WATER AND STEAM WATER BOTH BROUGHT RAPIDLY TO 10°C. IN TEST TUBES IN ICE-BRINE MIXTURE

Abscissae and Ordinates as in Fig. 5. Triangles, ice water samples; circles, steam water samples. In the latter case the samples freeze so slowly that the times given in three cases (circles with arrows) are those elapsing until the temperature of the brine mixture rose above the constant temperature. The reading at −3 is taken from Fig. 5 for it is difficult to maintain the brine for such long periods at a relatively constant temperature. In general, the freezing times in brine are faster than those in air.

by placing ice water and steam water, both at 10° as above, in a brine mixture at temperatures ranging from −2 to −15°C. Surrounded by the ice-brine mixture the water in the test tubes froze more rapidly than in the preliminary experiments in air, and the water which had been ice immediately before the test froze much faster than the steam water provided the temperature was not below −6°C. (Fig. 7). Finally, Dewar flasks (internal diameter 4.5 cm.) containing brine mixture were employed and samples of the water used in the *Euglena* and later *Spirogyra* experiments were tested at −5°C. at the time of renewal. To eliminate the possible influence of the internal surface of the test tube on the speed of freezing, many tubes were used and reversed in separate tests, i.e., the tube in which ice water had frozen rapidly in one test was used for the slow freezing of steam water in another test. In the Dewar flasks a typical 10 cc. sample of ice water would freeze in 10 to 15 minutes at −6°C., while steam water would remain unfrozen under the same conditions for as long as 45 minutes. All samples were tested immediately after preparation. Preliminary experiments dealing with samples a day old indicate that some of the difference persists for a considerable time, but further work is necessary before a definite time limit can be placed upon the hysteresis effect. Therefore, in experiments planned to test the effect of water polymers, it is essential that freshly prepared water be used, that this water should be renewed as frequently as practicable under the experimental conditions, and that, if possible, destruction of trihydrol by the addition of solutes should be obviated.

The recent work of Weiss and Nord (1933) indicates that enzyme solutions are more active after freezing which may help to explain some of the biological results. According to Larson's theory peroxide may be formed when trihydrol breaks down as shown by the guiacum test (Barnes and Larson, 1933).

Harvey (1933) in a recent comprehensive paper on the rate of diatom growth has considered the suggestion of one of us (T. C. B.) that the production of diatoms may be influenced by trihydrone molecules in the water from recently melted ice. Using *Nitzschia closterium*, he tested the possibility of different water molecules in the following way. Filtered sea water was enriched with phosphate, nitrate, iron citrate and sodium silicate and inseminated with the diatom. Fifty cc. portions were placed in small flasks to half of which were added 10 cc. of recently distilled water and to the other half 10 cc. of the same water which had been frozen and allowed to melt. Harvey states "The experiment was repeated several times and except in the case of one pair of flasks, a greater growth could be distinguished after several days where the ice water had been added." Counts in a representative pair of flasks showed 4,310 cells per cubic mm. with recently distilled water and 5,430 cells per cubic mm. with ice water. In another series, the sea water was partially frozen and allowed to melt, and "in each of the experiments the growth was perceptibly greater in the water which had been partially frozen." Another series of experiments made in November with less illumination did not show the difference. In the *Euglena* and *Spirogyra* experiments we also find that occasionally the effect does not appear, a fact which has not yet been explained. It is interesting that Harvey obtained an ice water effect in spite of the high salt content of his water samples.

Offant (1934) has described what we interpret to be an effect of water polymers on the heart rhythm. If K-poor

Ringer is treated with ultra-violet light it alters the heart rhythm but Offant finds, by irradiating water and salts separately that the effect is on the water molecules. Probably some change is produced in the higher polymer since radiation of heated water (simpler structure) has no effect. Radiation is a powerful agent in the destruction of trihydrol (cf. H. T. Barnes, 1929, p. 296).

Hegarty and Rahn (1934) have recently tested our water theories with *B. coli* cultures. They used ice water from sterile water blanks kept frozen for at least a day and steam water from a sterile Pyrex condenser. The waters were at once brought to 30° and peptone and beef extract added. In a typical run the population increased from 88,500 per cc. to 1,420,000 per cc. in ice water and from 103,500 to 700,000 in steam water. They write "dihydrol is changed strikingly only by vaporization which is also the sole process influencing the growth rate of *Bacterium coli*." Further details may be obtained from the original paper but it is interesting to note that their work indicates a lag in the polymer equilibrium of 4–12 hours.

It was formerly suggested (Barnes, 1932) that the colloidal water particles might render the water more active in a manner analogous to catalysis, but at the present time it does not seem prudent to go beyond the empirical finding that ice water will sustain *Spirogyra* and *Euglena* for a longer time than fresh steam water. The positive results with these holophytic cells also invite the consideration that polymerized water is involved in photosynthesis. The trihydrol or hexahydrol may be built up into a sugar molecule. If melted ice water were stimulating to plants only, it would still be a factor in the increase in the spring plankton as originally suggested (Barnes, 1932) and might help to explain the richness of plant forms in arctic waters. Hart (1934) regards this suggestion as "rather naïve" in view of the many factors involved (cf. Gran (1929), Braarud and Klem (1931)) but he considers the trihydrol hypothesis as an explanation of the abundance of plankton in cold water. Correspondents have mentioned that some algae do not show the same differences in ice water, and it may well be that various forms have an optimum trihydrol condition, depending on the species. Nor is it impossible that the water polymers have an *indirect effect*, as would occur if they influenced the concentration of catalytically active "unhydrated H ions" in stoichiometrically similar water samples. We have found no consistent pH difference, and both the biological effect and the freezing time phenomenon are evident when the pH is the same (5.9, 6.0, 6.2). This makes it improbable that the CO_2 content of the ice water is the chief factor, but Sutherland (1900) has pointed out that the solubility of substances in trihydrol may be quite different from that in the other water species. Hegarty and Rahn (1934) bubbled their water samples with air to prevent an O_2 deficiency effect.

We must also consider the possibility that the freezing time effect and even the biological results are influenced by the presence of dust particles in the water. Rice (1926) points out that distilled water contains about 25,000 suspended dust particles per cc. and these may be active catalytically, i.e., the oxidation of sodium sulphide is almost entirely a dust reaction and the photochemical decomposition of hydrogen peroxide more closely obeys Einstein's law of photochemical equivalence when dust is removed from the system. Also Pennycuick (1928, p. 1685) writes: "When a gaseous H—O—H molecule is captured through its auxiliary

field by some foreign substance, its exposed field is now more active than the normal, and further as it has surrendered some of its kinetic energy, it now acts as an efficient condensing agent towards other water molecules." However, we do not regard the dust nuclei as the most important factor for two reasons. (1) Burk (1928, p. 1632) doubts the generality of Rice's view and does not consider dust particles as a "great menace to sound investigation." He points out that the effectiveness of dust particles does not compare in magnitude with that of the walls of the vessel. In both the *Spirogyra* and freezing time experiments, the vessels were exchanged repeatedly in the tests, which would rule out any difference in the catalytic effect of the walls. (2) It does not seem probable that the ice water contained more dust particles than the recently condensed water for as Friend (1933, p. 301) states "Tyndall obtained optically pure water by melting clear block ice in a vacuum."

Most critics maintain that the polymerization equilibrium is established instantly. For example, La Mer and Miller (1933), although admitting that negative evidence such as the vapor pressure measurements of Menzies (1932) may be ascribed to insufficient sensitivity of the method, report no difference in the refractive index of water recently distilled as compared with water standing for several days. But La Mer and Miller fail to consider Sutherland's (1900, see p. 466) discussion of the Lorenz-Lorentz formula which suggests that the refractive index and the trihydrol concentration do not tend to diminish toward O° at the same rate. As was mentioned above, our claims apply especially to water from clear ice consisting of large crystals compared to condensed steam water. We admit that it is theoretically possible that the equilibrium is rapid; but if this is true, it would leave no explanation for the biological difference in water depending on its previous change of state, the striking difference in freezing times of ice and steam water, the differences in diamagnetism depending on thermal history (Wills and Boeker, 1932), and the exhaustion of the ice-forming power of water at low temperature by the removal of ice (H. T. Barnes, 1929 and Fig. 1 of this review).

CONCLUSIONS

In conclusion we wish to emphasize the importance of water as a neglected component in chemical and biological systems. It is recognized (cf. Heilbrunn, 1928; Adolph, 1930; Gortner, 1930; Kiesel, 1930) that water is the most important component of living matter but it is evident from the foregoing review that a great deal more information is needed on the physical side before we will be in a position to assign specific rôles to water in its various modifications in the living cell. The problem of "water metabolism" has received considerable attention (cf. Buchanan (1930), Adolph (1933), Barbour and Gilman (1934)). Duryee (1933) has supported the important theory that oxidation is inversely proportional to water content; but on the other hand Schieper (1929) holds that the addition of water to the body fluids of certain animals increases the respiratory rate, due on his theory to the osmotic work performed in resisting the disturbance of the salt equilibrium (for example, the gill movement frequency of *Ligia* increases in dilute sea water (Barnes, 1932a)).

Quite apart from the hypothesis that water polymers have specific effects on living matter and that the association equilibrium requires time, it is obvious that the variation of the ratio of water polymers as controlled by temperature,

which is firmly established by the numerous investigations reviewed above, will have to be considered when estimations are made of the physical state of natural waters (*e.g.*, great depths of the oceans, mountain lakes, saline lakes, hot springs, etc.). It might be worth while to apply the calculations of Sutherland and others to various aquatic environments, *i.e.*, deep sea water at a temperature near zero would have a molecular constitution similar to water at 100° for the large trihydrol content determined by the low temperature would be dissociated by pressure. For every atmosphere of pressure 0.00017 gram of liquid ice is dissociated at 0°C. and 0.0001 gram per atmosphere at 100° (Sutherland, 1900, p. 469). However, space forbids us from extending these speculations in the present review.

Looking back over the long list of interesting publications concerning the molecular constitution of water it is indeed surprising that the subject has been so sadly neglected in textbooks of physical chemistry. Even the important volume of Henderson (1927) dealing largely with the fitness of water for living organisms, makes no mention of water polymers. Henderson deals with the high specific heat of water as a unique and biologically important property but this remains unintelligible unless it is realized that the specific heat of water is largely made up of the heat of dissociation of trihydrol. From a consideration of the many forgotten properties of hydrogen oxide discussed by the authors whose papers have been summarized, it is clear that a fruitful field awaits further investigations of the biological significance of water. The present review is not complete—for example, we can but mention such important papers as that of Coolidge (1933) on the quantum mechanics of the water molecule, which do not deal directly with association—but we have selected typical papers dealing with each important aspect of the problem. If our researches on the biological properties of types of water stand the test of further criticisms, a more extensive review will be prepared.

SUMMARY

Experiments by the senior author (T. C. B.) indicated that condensed steam water and ice water differ in some way as judged by their effect on *Spirogyra*. A comparable difference was found by the authors in the effect of these types of water on *Euglena*. As this difference may prove to be due to the different molecular complexity of the water samples resulting from a change of state, it was thought advisable to prepare the present paper dealing with all significant investigations on the association of water and the properties which this may influence. The more important papers on "trihydrol" covering the period 1879 to 1933 are reviewed and a few other important contributions dealing with related water problems are briefly summarized. It is significant to note that the most recent comprehensive analysis of water structure (Rao, 1934) supports the old mono-, di- and trihydrol hypothesis. Additional data are given relative to the *Euglena* experiments and the freezing times of ice and steam water. It is concluded that all water contains "trihydrol" aggregates whose concentration varies with temperature and to a less extent with pressure and the concentration of solutes, and that there may exist a considerable time factor in the attainment of association equilibrium under certain conditions. Further, it is pointed out that the molecular complexity of water has well recog-

nized biological consequences such as the stability at ordinary temperatures of this compound of elements with such low boiling points as H and O; and the hypothesis is considered that the concentration of polymers in ice water may exert new and little known effects on certain types of living cells.

We wish to express our thanks for indispensable help from Professor Howard T. Barnes and Dr. William H. Barnes. We are also indebted for valuable information from Dr. E. Ernest Dorsey and the late Dr. E. W. Washburn and helpful criticism from Professor W. J. Crozier. We are of course entirely responsible for our interpretation of biological effects and for any errors which may have crept into the manuscript.

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HEAVY WATER AND METABOLISM

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LEWIS (1) first published his finding of the completely inhibitive effect of pure heavy water (D_2O) upon the germination of tobacco seeds, and the retardation of the same process by only 50 per cent heavy water; he followed this article with an account (2) of similar effects upon the growth of yeast and bacteria, and the fatal effects upon flatworms immersed in the heavy isotope. He cites the work of Pacsu (3) who found that 100 per cent heavy water retarded the normal rate of fermentation of sugar by yeast by about 89 per cent, while 60 per cent D_2O retarded the process by only about 37.5 per cent. Lewis' work on the mouse showed that this rodent suffered various deleterious effects and manifested great thirst, when allowed to drink only heavy water. Taylor, Swingle, Eyring, and Frost (4) had shown that flatworms, tadpoles, small fishes, and certain Protozoa were killed by immersion in 92 per cent heavy water for certain intervals, but that 30 per cent showed no lethal effects.

Heavy water, while not strongly toxic, exerts at high concentrations probably universal deleterious effects upon living organisms, just as do certain vitamines, hormones, and drugs. Like such substances also, heavy water in very dilute concentration exerts little or no effect differentiable from those of ordinary water, while certain intermediate concentrations appear to be highly stimulative to growth.

Thus Macht and Davis (5), using a sample of water containing only 1 part D_2O in 2000 parts H_2O found that this solution, compared with ordinary water, produced only a slight retardation of the germination of *Lupinus* seedlings, whether salts were added or not, no apparent differences in the fermentation of sucrose by yeast, no changes in the physiological behavior of injected mice or of immersed goldfish, or in the rhythmic behavior or response to drugs by surviving smooth muscle from various sources, and no changes in the blood pressure or respiration of injected cats. On the other hand, Barnes (6, 7) found that heavy water of about the same concentration increased the longevity of *Spirogyra* filaments, and led to a decrease of abscission, as compared with controls in distilled water, whether various salts or buffers had been added to each medium or not. Similarly Richards (8) using the same solution but studying a yeast (*Saccharomyces cerevesiae*) instead of a green alga, found that this fungus when grown in the heavier water produced a larger total volume of cells by 20 per cent, had a larger mean cell size by 3 per cent, and showed a dry weight 26 per cent greater than the controls cultured in ordinary water. A greater variation in individual cell size was found in the yeast cultured in the heavier water.

According to Barnes and Larson (9), *Oscillatoria* spread more extensively in the above fraction of isotope water than in ordinary water. They suggest that the observed heavy water effects may be due to its influence on enzymes; pancreatic amylase in the D_2O solution for 24 hours was less active than were controls in ordinary water. A zymase, exposed for 66 hours to the heavy isotope showed 10

per cent less CO_2 production than controls in ordinary water.

Both Barnes and Richards, who found unmistakable effects, used approximately the same concentration of solution as did Macht and Davis (specific gravities of 1.000061 vs. 1.000060 respectively) but apparently worked with more sensitive material, and utilized more delicate means of observation. Mayer (10) employing water containing 1 part deuterium to 213 parts protium (more than nine times as strong as that used by Barnes, Richards, and Macht and Davis) found that a nutrient solution made of this supported the development of mycellial felts of *Aspergillus* sp. which reached a weight (dry) sixteen times as great as that of controls grown under the same conditions, but using ordinary water as solvent. He also found several indications of marked stimulation by D_2O, with diminished fruiting, and irregular and localized distribution of spores on the surface.

Hevesy and Hofer (11) observed that goldfish (*Carassius auratus*) behaved normally in 0.5 mol per cent D_2O. They present evidence to show that the heavy isotope was readily taken up by the animals' tissues, and as readily given up again when the fish were returned to ordinary water.

Finally, Washburn and Smith (12) have shown that the growing willow performs an isotopic fractionation of combined hydrogen during synthesis of organic compounds, retaining in the sap and woody tissues greater amounts of D_2O than normally exist in water. No preferential absorption occurs on the part of the root membranes.

The biological properties of heavy water not only challenge the general physiologist, but must capture the interest of those engaged in studies of such composite sciences as ecology, oceanography, agriculture, and medicine.

Since it is known that brine ponds, salt lakes, and oceans have, presumably in the process of fractional evaporation, accumulated a greater-than-normal content of heavy water[1] would it not be of considerable value to know whether certain halophilic animals, plants, and bacteria found in such localities might have a tolerance, or even a need, for higher concentrations of heavy water[2] as they do for higher concentrations of dissolved salts?

Lewis (2) makes the suggestion that perhaps certain organisms may have an actual need for heavy water, and that experiments be made to analyze for both waters the tissues of plants and animals maintained in media of varying isotopic composition.

Certain it is that heavy water exerts very different effects upon the metabolism of organisms, according to its concentra-

[1] Bleakney and Gould (13) working at Princeton, have concluded that their closest approximation to the actual amount of D_2 in hydrogen from rain water is 1:5000.

Gilfillan (14) found a difference of 2.3 parts per million between the densities of carefully prepared distillates from sea-water (from the surface or from great depths) and distillates from laboratory tap water. He takes the isotopic identity of sea-water distillates from all depths as signifying that the sea has not reached equilibrium, and that the observed differences in D_2O content between sea and land waters are perhaps due to the differences in distillation rates of the two isotopes.

[2] Dole (15) determined the densities of distillates obtained from samples of water taken from the Atlantic Ocean, the Dead Sea, Great Salt Lake, and from hydrated mineral razorite, and found the values to be greater than those for fresh water by several parts per million, indicating a naturally occurring isotopic fractionation, presumably by distillation. Dole suggests, on the basis of others' work, that living organisms may select protium in preference to deuterium, but points out that the heavy isotope may be concentrated physiologically. He cites the work of Washburn and Smith (op. cit.) and reports an excess of deuterium in honey, benzene, and a kerosene over that in ordinary water by 4, 7, and 8 parts per million respectively. He suggests that such data from petroleum distillates may shed light upon the origin of petroleum.

tion. Experimentation on the relative concentrations of both waters for optimal growth in certain plants and animals of commerce would have a manifestly valuable application. Such experiments are probably in progress.

Hackh and Westling (16) recently suggested that heavy water, boiling at 101.42°C. as contrasted with the boiling point of ordinary water, may therefore evaporate more slowly from the human body than does the latter, and gradually thus becoming accumulated, may be responsible for the various retardations and inhibitions in protoplasmic activity characteristic of senescence.

The work of Washburn and Smith indicates some kind of selective retention of heavy water by the young willow, but if such a phenomenon were also found to be true for animals including humans, it would seem a rather colossal feat to attribute to differential evaporation alone, in view of the small differences in vapor pressure of the two water isotopes, and the numerous and intricate aspects of water metabolism, including the paths of water elimination, any of which might conceivably act somewhat selectively. Also, the mechanism proposed by Hackh and Westling could not account for senescence in marine and other aquatic animals.

The investigations of Washburn and Smith, and the speculative communication of Hackh and Westling are of help, however, in suggesting certain possibilities in the realm of medicine. It is well known that three types of animal tissue having the highest water content (excepting the body fluid and certain highly vascularized organs) are embryonic, germinal (ovaries, testes) and neoplasmic (cancerous growths). Cell division is more rapid in the first two classes, and often in the last class, than in normal, adult somatic tissue. While in the former three kinds, growth (addition of new cells) is taking place, in the latter, merely maintenance, or cell replacement is occurring. With fetal development, birth, adolescence and maturity ripening into age, the total water content of the body undergoes a gradual decrease from about 94 per cent in a three-months human fetus, 66–69 per cent at birth, to about 58 per cent in adult life, lessening continually with age (17, 18). Reproductive functions also lessen with the onset of senility. The incidence of cancer is far greater in the elderly than in youth or in adults at their prime.

If, during a gradual decrease in the total water content of aging animals, some degree of selective retention of heavy water occurred, somewhat comparable to the case of the young willow tree, by whatever mechanisms in operation, might not this accumulation reach concentrations, general or localized, sufficient to stimulate the maximum production of neoplasmic cells (just as certain ranges of heavy water concentrations stimulate the growth of algal and fungal cells), given the necessary accessory determinants? That certain accessory stimulants are present in neoplasmogenesis is indicated by the ease of excising or otherwise destroying incipient growths, the transplantability of certain tumors (19, 20), and the chemical inhibition (21) of "takes" in transplants. That, given favorable conditions for the occurrence of rapidly growing masses of cancerous tissue, heavy water at certain concentrations might act as an effective stimulant to the growth of such cells is suggested by reviewing the work of certain authors cited.

To Lewis' proposal that the relative proportions of the two hydrogen isotopes be determined in the tissues of organisms provided with heavy water at various

concentrations is added the suggestion that both normal and cancerous tissues of animals throughout the life span might be so analyzed with a view to throwing light on the question of a possible rôle played by heavy water in the stimulation of such growths.

ADDENDA

Since the preparation of this review, several articles have appeared. These should be mentioned in order to bring the review up to date.

H. S. Taylor (22), in a brief review of the chemical, physical, and biological work with heavy hydrogen at Princeton, mentions the initiation of work in one line of investigation which has been independently suggested in this present paper, concerning the effects of heavy water upon cancer cells. Taylor also mentions experiments by Dr. J. Pace which show that high concentrations of D_2O depress the catalytic decomposition of hydrogen peroxide by blood catalase.

Stewart and Holcomb (23) investigating the possible biological separation of heavy water, carefully fractionated and refractionated tap water, water from cow's milk, and from cow's urine, comparing the D_2O concentration in the distillates using the most recent and careful methods. They found no differences in the water from these various sources, but admit that further work must be done, especially with reference to heavy hydrogen in milk, urine, and other body fluids. The isotopic composition of respired water, water of perspiration, and the various body fluids still remains to be investigated, and attention should be paid to the question of alterations in composition with changes in physiological states such as aging and various pathological conditions.

Harvey (24), found that heavy water (85–95 per cent) did not prevent the luminescence of dried *Cypridina*, nor affect luminescence in a fresh water luminous bacterium, but diminished luminescence in a marine form, retarded the growth of luminous bacteria, killed a number of protozoa and rotifers, and did not kill bacteria nor irreversibly injure *Euglena*. The heavy isotope penetrates *Elodea* cells and slowly retards protoplasmic cyclosis. Harvey concludes, having eliminated the possible presence of traces of toxic impurities such as peroxide and nitrogen oxides, and in consideration of the slow and often reversible effects of heavy water, that "its action may be likened to that of a generally unfavorable environment leading to progressive changes in the cell." He suggests that the observed changes may result from "differential effects on the rate of biochemical reactions, which ordinarily proceed at a certain definite rate in relation to each other."

Harvey and Taylor (25) found, using the Warburg respirometer, that marine luminous bacteria, kept in salt and peptone cultures containing heavy water, underwent a decrease in respiration rate, the higher concentrations exerting the greatest effects. Luminescence was markedly decreased in 86 and 63 per cent D_2O. The writers noticed a similar reduction of respiration in a fresh water form, *Vibrio phosphorescens*, without appreciable reduction in luminescence.

Barnes (26), who is one of the chief students of the physiological effects of heavy water and the various hydrols (H_2O, $(H_2O)_2$, $(H_2O)_3$) upon single-celled organisms in particular has found that heavy water of low concentration (density of 1.000061) increased the rate of division of *Euglena* by more than 15 per cent, as compared with organisms kept in ordinary water, and that there were 2.3 times as many of the active forms in the water containing the heavy isotope as in the ordinary water. He suggests that D_2O in small quantities may be an essential part of living systems, and that perhaps in the case of *Spirogyra* and *Euglena* in hypotonic solutions, the reduction in enzymic hydrolysis may prolong cell life and thus allow opportunity for the increased cell division observed.

Woodard and Chesley (27) reported that gelatin absorbed in a given time 20 per cent less heavy water (from a 90 per cent D_2O solution) than did equal amounts in ordinary water. They stressed the importance of water absorption in life processes, and believe that their experiments with gelatin indicate a possible mechanism of the retardation of growth of plants or animals living in high concentrations of the heavy water isotope.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *1901 East Madison Street, Baltimore, Maryland, U. S. A.*

BRIEF NOTICES

EVOLUTION

MAN'S PLACE AMONG THE ANTHROPOIDS. *Three Lectures on the Evolution of Man from the Lower Vertebrates.*

By William K. Gregory. Oxford University Press, New York. $2.50. $8\frac{3}{4}$ x $5\frac{3}{8}$; vi + 119 + 5 plates; 1934.

These three lectures, delivered at University College and Oxford University, represent Professor Gregory's rejoinder to Professor Wood Jones' *Man's Place Among the Mammals* (reviewed in the QUARTERLY, Vol. 5, page 370). Professor Gregory, marshalling a vast amount of authoritative evidence, attacks the latter's thesis that man has been derived not from any early ape at all, but from a far older and long extinct branch of the Primates; that is, that man is distantly related to the spectral tarsier of Borneo and the Philippines. Taking sides in this controversy seems neither judicious nor necessary.

MARINE MAMMALS. *Contributions to Palaeontology. Carnegie Institution of Washington Publication No. 447.*

By Earl L. Packard, Remington Kellogg, and Ernst Huber. Carnegie Institution of Washington, D. C. $4.00 (paper); $5.00 (cloth). 10 x $6\frac{7}{8}$; 136 + 8 plates; 1934.

Four papers are included in this publication of the Carnegie Institution of Washington: A New Cetothere from the Miocene Astoria Formation of Newport, Oregon, by Earl L. Packard and Remington Kellogg; The Patagonian Fossil Whalebone Whale, *Cetotherium moreni* (Lydekker), by Remington Kellogg; A New Cetothere from the Modelo Formation at Los Angeles, California, by Remington Kellogg; Anatomical Notes on Pinnipedia and Cetacea, by Ernst Huber.

In the first paper in the series will be found a partial list of fossil mollusks from the Astoria formation (Middle Miocene) of Lincoln County, Oregon; a list of specimens of fossil marine mammals obtained from the Tertiary of the Newport region; and a map of a portion of the Oregon coast showing localities of fossil marine mammals. Measurements of all bones described in the first three papers are arranged in tabular form in the texts. The material in the last paper in the group has been arranged by Professor A. Brazier Howell from manuscripts and notes left by the late Ernst Huber.

CONTRIBUTIONS TO PALÆONTOLOGY. *Papers Concerning the Palaeontology of California, Arizona, and Idaho. Carnegie Institution of Washington Publication No. 440.*

Carnegie Institution of Washington, D. C. $2.25 (paper); $3.25 (cloth). 10 x $6\frac{3}{4}$; 135 + 28 plates; 1934.

The detailed data in these papers are carefully tabulated and subdivided. Each article has a content outline following its

title. The volume is well supplemented throughout with text figures and plate illustrations. It contains the following papers: Tertiary mammals from the auriferous gravels near Columbia, California, by John C. Merriam and Chester Stock; Notes on the geologic section near Columbia, California, with special reference to the occurrence of fossils in the auriferous gravels, by George D. Louderback; Perissodactyla from the Sespe of the Las Posas Hills, California, by Chester Stock; Carnivora from the Sespe of the Las Posas Hills, California, by Chester Stock; Anchiteriine Horses from the *Merychippus* Zone of the North Coalinga District, California, by Francis D. Bode; Pleistocene mammalian fauna from the Carpinteria asphalt, by Robert W. Wilson; The Coconino sandstone—its history and origin, by Edwin D. McKee; A rodent fauna from later Cenozoic beds of Southwestern Idaho, by Robert W. Wilson.

THE EVOLUTION OF THE VERTEBRAL COLUMN. *A Contribution to the Study of Vertebrate Phylogeny.*

By H. F. Gadow. Edited by J. F. Gaskell and H. L. H. H. Green. University Press, Cambridge; The Macmillan Co., New York. $6.75. 9¼ x 6; xiv + 356; 1933.

The aim of this book is "to put together the evidence of the various lines of development of the vertebrae as a guide to the general morphological scheme of vertebrate evolution." For over forty years the author, late Strickland Curator and Reader in Vertebrate Morphology in the University of Cambridge, had been interested in the morphological problems of the vertebrate phylum. At the time of his death he had accumulated much of the material for the present volume. The editors, J. F. Gaskell and H. L. H. H. Green, are responsible for the final arrangement of the latter part of the book, as well as for certain other necessary changes which the manuscript indicated. They are also responsible for the selection of the many illustrations.

A lengthy bibliography and an index are included in the volume.

SCHIMPANSISCH, URMONGOLISCH, INDOGERMANISCH.

By Georg Schwidetzky. Deutscher Verlag, Leipzig. 5 marks. 8⅞ x 5¾; 94; 1933 (paper).

In this interesting but not altogether convincing little book the author attempts to derive an evolutionary relationship between the chimpanzee and man, by a philological comparison of the chimpanzee "language" with that of various tribes of the Mongolian and Indo-Germanic races. He compares words used by man with those of the Yerkes-Learned "word list" of the chimpanzee. The book is equipped with an extensive bibliography and an index.

PLANT LIFE THROUGH THE AGES. *A Geological and Botanical Retrospect. Second Edition.*

By A. C. Seward. The University Press, Cambridge; The Macmillan Co., New York. $8.00. 9 x 6; xxi + 603; 1933.

Mention has already been made in these pages of the first edition of this volume which was published in 1931 (Volume 7, page 101). The second edition is unchanged except for a few alterations and corrections in the text and the addition of a short list of references.

GENETICS

HEREDITY AND THE SOCIAL PROBLEM GROUP. *Volume I.*

By E. J. Lidbetter. Longmans, Green and Co., New York. $7.50. 9¾ x 7¼; 159 + 26 folding charts; 1933.

For many years the author, aided by the English Eugenics Society, has conducted an investigation on individuals residing in a Poor Law district of East London, who normally resort to public assistance. The scope of the study is: (1) To ascertain the

measure of family chargeability, and, as far as possible, reduce the results to pedigree form. (2) To measure the periods of chargeability against the periods of independent support. (3) To ascertain the age of onset and the incidence of repetition in recurrent cases. (4) To secure records of fertility and survival in the several classes. (5) Generally to compare the ascertained family chargeability with individual chargeability.

This volume is limited to a report of part of the data and consists of twenty-six pedigrees with statistical and biographical notes. A survey of the charts shows that the introductory observations of the author are well founded. There is a very high degree of assortative mating and frequent appearance in each generation of mental and physical defectives.

It can be foreseen that the conclusions will be of interest and importance.

ENFANCE ET HÉRÉDITÉ.

By A. Lesage. Masson et Cie, Paris. 20 francs. 7⅞ x 5¼; 104 + 10 plates; 1933 (paper).

A brief summary of clinical notes on hereditary taints observed in infants, in particular cranial malformations and signs of arthritic diathesis. The author desires to emphasize the fact that many obscure ailments are not to be attributed to external causes but to faulty heredity, and therapy should be directed accordingly.

GENERAL BIOLOGY

ADAPTATION. ÉCOLOGIE ET BIOCŒNOTIQUE. *Actualités Scientifiques et Industrielles 103. Exposés de Biologie Écologique.*

By Marcel Prenant. Hermann et Cie, Paris. 15 francs. 10 x 6¼; 60; 1934 (paper).

The central idea of this brilliant and penetrating study is the necessity for the physiological analysis of the environment if the phenomenon of adaptation—which is essentially the correlation between organism and environment—is to be understood. The discussion begins with a chapter on the tremendous power of living material to expand in space and time. As the author truly says this is the essential fact of adaptation, and indeed the central idea of biology. This is followed by a chapter on the great complexity of the physical environment, in which it is emphasized that, for example, the limits of viability of an organism relative to a particular environmental agent such as temperature, as determined by the physiologist in the laboratory, rarely agree with those found by the ecologist in nature. The next chapter discusses the interaction of organisms in nature, on the basis particularly of the work on experimental populations of Pearl with *Drosophila*, Park with *Tribolium*, and the mathematical analyses of Lotka and Volterra. A final chapter on biocenosis and ecology argues for the reality of true association of living things, with concomitant biological interactions. Professor Prenant reaches the general conclusion that the relation between organism and environment cannot be completely and realistically analyzed in physico-chemical terms alone. There are four short appendices and a bibliography of seven pages.

Altogether this little book is a contribution to theoretical and philosophical biology of the very first rank of importance.

THE JUNGLE IN SUNLIGHT AND SHADOW.

By F. W. Champion. Charles Scribner's Sons, New York. $7.50. 10 x 7½; xvi + 270 + 95 plates; 1934.

Of the making of books about the jungle and its inhabitants there is no sign of anything approaching an end. But this particular one will stand for a long time in a class by itself. In the first place the author is a trained zoologist in the Indian Forest Service, and writes an intelligent and charming text, informed with an immense knowledge of the jungle and its denizens. In the second place his illustrations, of which there are some ninety-five full page half-tone plates, are simply and literally superb. And the book is not, like so many in its general class, merely about elephants and/or tigers. Mr.

Champion shows us a wide range of rarer animals in his zoo. His chapters on the ratel or honey-badger and the pangolin make definite contributions to knowledge. Strange creatures both are.

No student of ecology or animal behavior should miss this book. And we suppose all sportsmen will want it on their library shelves, though one can but wonder what a hunter's reaction would be if he were really to grasp Mr. Champion's viewpoint about wild life. For he never harms or kills an animal. His sympathy with living nature is without limits or bounds. Yet he is no sentimentalist, and his discussion of the balance of nature is one of the most realistic and penetrating to be found anywhere in biological literature.

There is a detailed index and a brief glossary of Indian vernacular terms.

CONTRIBUTION À L'ÉTUDE DU PEUPLEMENT ZOOLOGIQUE ET BOTANIQUE DES ÎLES DU PACIFIQUE. *Mémoires de la Société de Biogéographie IV.*

By L. Berland, J. Berlioz, E. H. Bryan, E. Cheesman, L. Joleaud, L. Chopard, L. Germain, A. Guillaumin, K. Holdhaus, Mumford and Adamson, P. Rivet, L. Seurat, C. Skottsberg, E. Topsent, C. Vallaux. Paul Lechevalier et Fils, Paris. 70 francs. 10 x 6½; 288; 1934 (paper).

This is a collection of sixteen papers by as many authors on plant and animal distribution on the islands of the Pacific Ocean. Four papers deal specifically with insects, three with vascular plants, and there are single papers on sponges, spiders, birds, paleontology, and human ethnology. Other papers deal with the flora and fauna of certain archipelagoes. It appears from these papers that serious attempts are well under way to obtain systematic and representative collections of the flora and fauna of the smaller islands of the Pacific in place of the casual and sporadic collections hitherto available. Three of the papers are in English and one is in German. All of the articles are accompanied by bibliographies and a few of them by maps.

NATURE CHATS. *A Year Out-of-Doors.*

By John H. Furbay. Science Press Printing Co., Lancaster, Pa. $1.75. 8⅛ x 5¼; xv + 255; 1933.

Unless modern youth is considerably less "hard-boiled" than it claims to be, this volume will not do much to increase interest in nature study. There is more poetry than nature to the book. There are nearly fifty illustrations, all but one or two of which are pen and ink drawings. They do nothing to redeem the book.

Wasps do not store any food. Some honey is made for feeding the young wasps, but it is never stored in the nest. They seem to live only for the pure joy of living. They remind us of the words of Burroughs who said that the game of life itself is worth all the trouble and pain it takes to play it. They work all summer building a nest which they will never live in; yet how happy they seem to be while doing it. And, after all, our own lives are not very different.

LES PROBLÈMES DE L'HÉRÉDITÉ ET DU SEXE. *Bibliothèque Générale Illustrée. 23.*

By Jean Rostand. Les Éditions Rieder, Paris. 20 francs (paper); 25 francs (cloth). 8 x 6; 92 + 60 plates; 1933.

M. Rostand writes well and lucidly on Mendelism, the chromosomes, sex, parthenogenesis, mutation, influence of environment on organisms, and eugenics, making this one of the best brief accounts, designed for the general reader, we have seen on these subjects. The author has provided a short bibliography of general treatises, and sixty excellent photographic plates.

LA CELLULE ET LES PROTOZOAIRES. *Actualités Scientifiques et Industrielles 106. Leçons de Zoologie et Biologie Générale.*

By Georges Bohn. Hermann et Cie, Paris. 18 francs. 10 x 6½; 121; 1934 (paper).

REPRODUCTION. SEXUALITÉ. HÉRÉDITÉ. *Actualités Scientfiiques et Industrielles 120. Leçons de Zoologie et Biologie Générale.*

By Georges Bohn. Hermann et Cie, Paris. 15 francs. 10 x 6½; 89; 1934 (paper).

These two brochures constitute the first two numbers of a series of five designed for the use of students of general biology and zoology. The first treats the cell and

protozoa; the second embryonic mechanisms, sexuality and genetics. They are well written, and the illustrations and printing are good.

IDEEN UND IDEALE DER BIOLOGISCHEN ERKENNTNIS. *Beiträge zur Theorie und Geschichte der biologischen Ideologien.*

By Adolf Meyer. Johann Ambrosius Barth, Leipzig. 9.75 marks. 9¼ x 6¼; xiii + 202; 1934 (paper).

[An extended review of this book will appear in a later number. EDITOR.]

CONFÉRENCES FAITES AU LABORATOIRE DE MICROBIOLOGIE DE LA FACULTÉ DE PHARMACIE DE NANCY. *Fascicule VI.*

Laboratoire de Microbiologie de la Faculté de Pharmacie, Nancy. 9½ x 6¼; 37; 1934 (paper).

HUMAN BIOLOGY

REMINISCENCES (MAINLY PERSONAL) OF WILLIAM GRAHAM SUMNER.

By A. G. Keller. Yale University Press, New Haven, Conn. $2.00. 8¾ x 6; 110; 1933.

In an age when the *laissez-faire* viewpoint is moribund—or is it? We shall know better after next November—it might seem that a figure like Sumner had lost his significance. It is true that Roosevelt has repopularized—and incidentally misapplied—his once famous phrase, "The Forgotten Man," but Sumner's Forgotten Man, "the clean, quiet, virtuous, domestic citizen, who pays his debts and his taxes," stands to lose rather than to gain by the New Deal. Yet it is our loss if we forget the strictures of an honest and forthright critic. There is certainly no lack of timeliness in the following passage, for instance:

> The government is to give every man a pension, and every man an office, and every man a tax to raise the price of his product, and to clean out every man's creek for him, and to buy all his unsalable property, and to provide him with plenty of currency to pay his debts, and to educate his children, and to give him the use of a library and a park and a museum and a gallery of pictures. On every side the doors of waste and extravagance stand open; and spend, squander, plunder, and grab are the watchwords. We grumble some about it and talk about the greed of corporations and the power of capital and the wickedness of stock gambling. Yet we elect the legislators who do all this work. Of course, we should never think of blaming ourselves for electing men to represent and govern us, who, if I may use a slang expression, give us away? What man ever blamed himself for his misfortune? We groan about monopolies and talk about more laws to prevent the wrongs done by chartered corporations. Who made the charters? Our representatives. Who elected such representatives? We did. How can we get bad law-makers to make a law which shall prevent bad law-makers from making a bad law? That is, really, what we are trying to do. If we are a free, self-governing people, all our misfortunes come right home to ourselves and we can blame nobody else. Is any one astonished to find that men are greedy, whether they are incorporated or not? Is it a revelation to find that we need, in our civil affairs, to devise guarantees against selfishness, rapacity, and fraud? I have ventured to affirm that government has never had to deal with anything else.

The writer of these reminiscences was a student of Sumner's and later his colleague and successor. A systematic biography of Sumner having been already given to us by Starr, Keller aims rather to perpetuate Sumner's personality, his influence in clearing his students' minds of cant, the personal kindliness that lay behind a somewhat forbidding exterior. One characteristic story is of his address to a convention of school teachers which was giving its chief attention to questions of pedagogical methodology.

> When I was in college, I knew a fellow who got all worked up over *how* to study. He had lots of theories. He tried it sitting down, lying down, standing up, standing on one leg, and so on. When the examination came, he flunked and was dropped from college. He hadn't studied at all. He had spent his time getting ready to do something. He didn't know anything.

. . . . SOMETHING NEW OUT OF AFRICA.

By HW. Pitman Publishing Corp., New York. $5.00. 9½ x 7⅛; xx + 208 + 4 folding maps; 1934.

We really do have something new in HW's account of his travels along the air routes of Africa. Having commanded the Squadron of the Royal Air Force in the Sudan

he is thoroughly versed in the art of flying in this land and not only for the prospective pilot but for the air traveler as well his report of conditions and of the technique of dealing with them from a flyer's viewpoint is invaluable.

Over one hundred excellent photographs, many taken from the air, depict Egyptian pyramids and temples, Africans in their native costume or rather lack of costume, and herds of wild animals in their natural habitat. Some of the latter are striking illustrations of the blending of the animals with the landscape. There are several examples of Abyssinian art, one of them being a colored reproduction of a pictorial narration of the story of the Queen of Sheba and how the wicked King Solomon "done her wrong."

It is interesting to learn that the noise of an airplane at a reasonable height does not alarm the wild animals to any great extent. Maps keep us informed of our whereabouts and, since use of them does not involve a complicated system of folding and unfolding, we really use them with ease and interest. The author informs us that at last the airplane can be the main instrument in solving a difficult and serious problem: the smuggling of slaves and other contraband. A boat hidden behind a reef is not hidden long if one can search from above. The method of "tracking down" the boats and the inspection process reads like a new adventure story.

HW is thoroughly in earnest about the importance of developing air transportation in a continent which, he feels, needs foreign intervention but so far gains slowly under it. This is due largely to the different climatic conditions, to the different policies of the various countries in their colonies, and to the natives themselves, who are slow to desire progress, scattered and impossible to unite, being bound often by tribal superstitions that go back for hundreds of years.

Gordon and Kitchener return to us in the vivid descriptions and excellent photographs of Khartoum and of the now deserted city of Suakin. HW has given us an extremely readable travel story. He has not overstressed the distinguished passengers, such as the Prince of Wales and the King of the Belgians, who have flown with him, but has given a modest and appropriate tribute to them, remembering that this book is on Africa and what "air mindedness" has done and can do for the continent.

FIVE FUR TRADERS OF THE NORTHWEST. *Being the Narrative of Peter Pond and the Diaries of John Macdonell, Archibald N. McLeod, Hugh Faries, and Thomas Connor. Edited by Charles M. Gates. University of Minnesota Press, Minneapolis.* $3.50. 8¼ x 5⅜; vii + 298; 1933.

Peter Pond, the author of the first of these documents, was an adventurous Yankee of the eighteenth century who began his career as a provincial trooper in the French and Indian wars and took part in Abercromby's disastrous expedition against Ticonderoga. About 1765 he established himself as a trader at Detroit and for more than twenty years was engaged in trading and exploration in the Northwest. Much of his narrative was unfortunately destroyed as waste paper; the greater part of what remains describes his explorations in the Upper Mississippi valley in the years 1773–1775. The following account of the mourning customs of the Fox Indians illustrates both his libertarian spelling and the vividness of his descriptions:

We asended that River til we Cam to a High Pece of Ground whare that Nation yous to Entar thare Dead when thay Lived in that Part. We stopt hear awhile finding Sum of that Nation on the Spot Who Came thare to Pay thare Respect to thare Departed frend. Thay Had a small Cag of Rum and sat around the grave. Thay fild thar Callemeat [Calumet] and Began thar saremony By Pinting the Stem of the Pipe upward—then giveing it a turn in thare and then toward ye head of the Grav—then East & West, North & South after which thay smoaked it out and fild it agane & Lade [it] By—then thay took Sum Rum out of the Cag in a Small Bark Vessel and Pourd it on the Head of the Grave By way of giving it to thar Departed Brother—then thay all Drank themselves—Lit the Pipe and seamed to Enjoi themselves Verey well. Thay Repeated this till the Sperit Began to Operate and thare harts Began to Soffen. Then thay Began to Sing a Song or two But at the End of Every Song thay Soffened the Clay. After Sumtime Had Relapst the Cag had Bin Blead often. Thay Began to Repete the Satisfaction thay had with that friend while he was with them and

How fond he was of his frends While he Could Git a Cag of Rum and how thay youst to Injoy it togather. They Amused themselves in this manner til thay all fell a Crying and a woful Nois thay Mad for a While til thay thought Wisely that thay Could Not Bring him Back and it would Not Due to Greeve two much —that an application to the Cag was the Best Way to Dround Sorrow & Wash away Greefe for the Moshun was soon Put in Execution and all Began to be Marey as a Party Could Bea. Thay Continued til Near Nite. Rite Wen thay Ware More than Half Drunk the men began to aproach the females and Chat frelay and apearantley friendley. At Lengh thay Began to Lean on Each other, Kis & apeared Verey amaras. . . . . I Could Observe Clearley this Bisiness was first Pusht on by the Women who made thare visit to the Dead a Verey pleasing one in thare Way. One of them who was Quit Drunk, as I was By [my] Self Seating on the Ground observing thare Saremones, Cam to me and askt me to take a Share in her Bountey. . . . . But I thought it was time to Quit.

At this time Pond was an independent trader; later he took part in organizing the Northwest Company of Montreal, of which the four diarists of this volume were partners or clerks. Macdonell's diary gives a narrative of the journey along the main thoroughfare to the Northwest: from Montreal by the Ottawa River and Lake Nipissing to Lake Superior and thence by the Lake of the Woods to Lake Winnipeg. McLeod's diary describes the daily life at a post on the upper Assiniboine, Faries' at the Rainy Lake post near the Lake of the Woods, and Connor's at one in the St. Croix valley in what is now eastern Minnesota.

The fur trader had to be a tough baby. A weakling would have had little success in collecting the debts which the Indian hunters owed him, circumventing his rival traders, keeping his hunters on their job of supplying the post with meat, and disciplining or sometimes defending his post against "drunk and troublesome" Indians.

The University of Minnesota and the Minnesota Society of the Colonial Dames of America may well feel proud of this scholarly and beautifully printed volume. If some other patriotic societies would confine their activities to such worthy enterprises as this they might come to be regarded as useful organizations rather than as public nuisances.

ETHICS AND MORAL TOLERANCE.

By Arthur K. Rogers. The Macmillan Co., New York. $2.50. $7\frac{3}{4}$ x $5\frac{1}{2}$; v + 323; 1934.

This book is addressed to a generation for which the traditional sanctions have lost their force. The problem therefore arises: should each man do what is right in his own eyes, so far as this does not trespass too radically on the well being of others, and concede a similar privilege to everyone else, or is there a more public hierarchy of values by which a man's acts may be assessed? From his analysis of the nature of values Professor Rogers concludes that they consist ultimately in the individual sentiment of approval or disapproval. Yet this conclusion need not necessarily imply our first alternative. The general likeness of human nature furnishes a basis, not for rigid moral criteria, but for "a somewhat indeterminate and plastic goal which exercises an emotional compulsion." We cannot profitably argue with the tiger on ethical subjects; he is what he is, and any condemnation of his lack of our sentiments is irrelevant. Nor can we argue with the tiger in human form; only on the supposition "that a man's present judgment does not exhaust his potential capacities of insight, and that in proportion as this genuine nature comes to light his ways of judging and of feeling may be expected to approximate to ours" have we the right to indulge our moral feelings. This is not a doctrine which encourages moral zealotry but rather the attempt to understand the other fellow's viewpoint, even though finally we may not agree with him.

The man who indulges indiscriminately in moral indignation and who hugs his moral antipathies to his bosom as a proof of his finer sensibilities is on the road to developing qualities of doubtful social merit; the hatred of injustice—a thing quite indispensable in morality—is likely to turn sour and become an animosity toward human beings who outrage our sensibilities or flout our prejudices. Like any other natural feeling indignation must be disciplined before it can become a virtue, and a part of this discipline will consist in shunting it from our human fellow to the obnoxious qualities which, though they may fill our eye for the moment, are certainly not the whole of him.

THE CHINESE. *Their History and Culture. Volumes I and II.*

By Kenneth S. Latourette. The Macmillan Co., New York. $7.50 per set. 8¾ x 5¾; Vol. I, xiv + 506; Vol. II, 389 + folding map; 1934.

These two volumes belong with the group of the most important recent books on China. The writer brings vividly before the reader China's brilliant past and the causes of her present chaotic state. A great race, more nearly uniform than India, Europe or America, until recently separated from the rest of the world by barriers of mountain, desert and water, China developed her political and social institutions, her philosophy and economic life free from foreign influences. For over 2,000 years the political framework of China was little changed. Furthermore she was the great teacher of her immediate neighbors, especially the Koreans and the Japanese. Within the last century this great civilization has been in the process of change. In Volume I the author discusses the geography and natural resources of China and gives a summary of the nation's history from the beginning to the present. Volume II deals with population and the main phases of the culture and institutions of the country as they developed before the coming of the European and the modification that European culture imposed upon them. A bibliography is appended to each chapter. A section is included giving proper names and Chinese words used in the text and their corresponding Chinese characters. There is a carefully prepared index and a large map is attached to the final page.

IBN SA'UD. *The Puritan King of Arabia. By Kenneth Williams. Jonathan Cape, London.* 8s. 6d. net. 8 x 5⅜; 299; 1933.

His Majesty King Abdul Aziz ibn Abdul Rahman ibn Faisal as Sa'ud, more handily known as Ibn Sa'ud, is without question one of the very greatest figures, if not in reality quite the greatest, now living in this imperfect world. In the history of Islam he bids fair to rank second only to the Prophet Muhammad himself. His life story, which is simply, accurately and fairly told in this volume, is a mine of interest for the serious student of human biology.

In exile as a youth, and with nothing but the force of his own character and personality in the way of assets, this Cromwell of Arabia has made himself the absolute sovereign of nearly the whole of that great peninsula, and would undoubtedly by now be ruling the remainder had it not been for the interference of certain of the great powers. In his personal and public life he obeys literally the tenets of the most primitive form of the Islamic religion. But at the same time he employs every device of modern applied science, radio, the airplane, automobiles, etc., to aid him in his job of conquering and ruling. Ruthless as he can be and repeatedly has been, he is as much beloved as feared by his people, as anyone must be who is to rule the Badawin for long. In his dealings with other countries, which have been trying and difficult, he has exhibited a patience and intelligence of the highest order. As a diplomat he stands in the front rank.

The book is quietly and conservatively written, and is well documented and indexed. We recommend it.

MATERNAL MORTALITY AND MORBIDITY. *A Study of Their Problems.*

By J. M. Munro Kerr. William Wood & Co., Baltimore. $8.25. 9¾ x 7¼; xviii + 382; 1933.

The author of this book has been for many years professor of midwifery in the University of Glasgow and obstetric surgeon in the Glasgow Royal Maternity and Women's Hospital. His purpose in writing this book is to assemble all available information concerning maternal mortality and morbidity that has been contributed by different sections of the medical profession. The material is arranged under four general headings: (1) Causes; (2) Prevention; (3) Service and (4) Organization. Chapter VI on "Maternal morbidity and subsequent disablement" is

contributed by Dr. Donald M'Intyre, and Chapter VII on "Neonatal death and disablement," by Professor G. B. Fleming. In a group of four appendices other phases of the general subject are discussed. It is the author's belief that only by full co-operation of the many different services and agencies concerned with maternal welfare can the present unsatisfactory level (for England and Scotland) of maternal mortality and morbidity be altered.

The volume includes illustrations, a considerable mass of statistical data, a design of a maternity hospital with suggestions for organization and staffing, and an index.

THE DISCOVERERS OF THE FIJI ISLANDS. *Tasman, Cook, Bligh, Wilson, Bellingshausen.*

By G. C. Henderson. John Murray, London. 18 shillings net. 9 x 5¾; xviii + 324 + 37 plates and charts; 1933.

To the average reader this will be merely an interesting book on discoverers of the Fiji Islands. Only a relatively small number will appreciate the historical importance of the work. Professor Henderson, in order to clear up the doubt which existed concerning the exact discoveries made by different navigators, provided himself with reports, charts and drawings, discoverers' log-books, etc., and made several cruises through the archipelago, tracing out the courses of the different voyages and their various discoveries. The great names in Fiji exploration are:—Tasman, who set sail from Batavia in 1642 and made one of the great voyages of discovery recorded in history; Captain Cook; William Bligh, of *Bounty* fame; James Wilson, with whose voyages in 1797 began the history of Protestant Missions in the South Pacific; and Fabian von Bellingshausen, a Baltic German in the service of the Russian Government, whose journal, which has never been translated into English, contains much of interest concerning the natives of Ono-i-lau. Numerous extracts of the navigators' journals are included in the volume, also copies of their charts. The volume is abundantly illustrated and contains in a pocket at the end a large map of Fiji showing the tracks of the discoverers. There is an index.

MATERNAL MORTALITY IN NEW YORK CITY. *A Study of All Puerperal Deaths 1930–1932.*

By the New York Academy of Medicine Committee on Public Health Relations; Ransom S. Hooker, Director of the Study. The Commonwealth Fund, New York. $2.00. 9 x 6; xxi + 290; 1933.

In 1930, with the financial aid of the Commonwealth Fund, a committee of the New York Academy of Medicine courageously undertook to determine the essential causes of the alleged high maternal mortality in the United States. The committee, composed of competent and highly trained obstetricians and public health workers, investigated with the greatest care the pertinent details of 2,041 maternal deaths in New York City. As a result of the most meticulous scrutiny of each case it was concluded that 1,343 fatalities would have been preventable " . . . . if the care of the woman had been proper in all respects." Responsibility for 61 per cent of the preventable deaths was placed upon physicians, for 37 per cent upon the patients themselves, and 2.2 per cent were charged to midwives. The direct and indirect causes of these deaths varied widely, the committee estimating that fully 60 per cent were brought about by " . . . . some incapacity in the attendant; lack of judgment, lack of skill, or careless inattention to the demands of the case." Thirty-one pages of tables included in the appendix indicate the large amount of data collected and it may be hoped that a much more detailed analysis will be made. The book is a classic; it is extremely well written and should be in the library of all persons who are truly interested in public welfare.

THE ABYSSINIAN AT HOME.

By C. H. Walker. The Sheldon Press, London. 7s. 6d. net. 7½ x 5; xii + 220; 1933.

In the preface the author states that "this book is a translation of Amharic notes, which are the statements of natives taken down in their actual speech and pieced together under the appropriate subject so as to read more harmoniously." These notes describe some of the beliefs, ideas and customs regarding religion, personal relations and property. However, there is no indication how deeply these pervade and influence individual action. Religion apparently dominates all phases of life but in somewhat the same detached and formalistic fashion that it affects the people of Southern Europe. Money is an all important factor, the form of reparation for most misdeeds and the means of obtaining justice. Women are considered fickle and therefore are not allowed to take oaths and their promises have no value. In general they seem to have as great a freedom as in some of the occidental countries and through marriage become, in financial matters at least, partners of their husbands.

Being entirely objective though not complete as stated, this book offers data of importance for sociologic analysis and is also very interesting.

There are a glossary of Amharic words and an index.

MATERNAL DEATHS. *A Brief Report of a Study Made in 15 States. Bureau Publication No. 221.*

By U. S. Department of Labor, Children's Bureau. U. S. Government Printing Office, Washington. 5 cents. 9⅛ x 5⅞; iv + 60; 1933 (paper).

An abstract of a full report of a study made by the U. S. Children's Bureau of all maternal deaths which occurred in thirteen states in 1927 and in these same states and two others in 1928. The report is divided into twelve sections. The first two deal with general considerations and maternal care. The next nine deal with specific causes of death. Each section includes statistical tables and charts and concludes with comment by the Advisory Committee. The final section is devoted to recommendations by the Advisory Committee, both to the medical profession and to the general public, for action looking to prevention of maternal deaths.

SELECTED REFERENCES IN EDUCATION, 1933. *Supplementary Educational Monographs No. 41.*

By Department of Education, University of Chicago. University of Chicago, Chicago. 90 cents. 9⅜ x 6½; x + 190; 1934 (paper).

After the United States Office of Education was forced to discontinue the *Record of Current Educational Publications* in 1932, the *School Review* and *Elementary School Journal* started a coöperative enterprise to get out monthly lists of selected references in education. This volume is a collection of these monthly lists for the year 1933.

The topics under which the items are grouped and the names of the specialists preparing the lists are presented in the Table of Contents. The items within each list are arranged alphabetically according to authors. This arrangement, it is believed, obviates the need for an index.

TOTARAM. *The Story of a Village Boy in India To-day.*

By Irene Mott Bose. The Macmillan Co., New York. $1.90. 8½ x 5⅝; xvi + 118; 1933.

Totaram is just a dear, every day little village boy, much like all boys with their favorite haunts, pastimes and love of stories. Through this book we learn much of the folk lore of India. The author is an American who lives in Nagpur, in the Central Provinces of India. In a nearby village she carries on a demonstration garden and chicken run and teaches weaving, and there she has heard many of the tales she relates. Totaram is friendly and any little boy would be pleased to meet him and learn about his country. The book is written for a child by one who understands and loves children.

THE MYSTERY AND LORE OF MONSTERS. *With Accounts of Some Giants, Dwarfs and Prodigies.*

By C. J. S. Thompson. Williams and Norgate, London. 7s. 6d. net. 8½ x 5⅝; 256 + 36 plates; 1934.

A well-written and abundantly illustrated popular treatise for the general reader on biological monsters of all sorts. As D'Arcy Power says in his too-brief foreword this is a book "which would have delighted the hearts of those inveterate sight-seers, Mr. Samuel Pepys and Horace Walpole." The material is treated in two substantially equal parts, the first general and the second devoted to giants, dwarfs and prodigies. There is a substantial bibliography and a detailed index. This book will usefully adorn any library; whether that of a gentleman or that of an undergraduate biological laboratory.

SEMEIOTICA DELLA COSTITUZIONE. *Dottrina e Metodologia Costituzionale Morfologica e Funzionale. Estratto dal Trattato di Semeiotica.*

By G. Viola. Dottor Francesco Vallardi, Milan. 9½ x 6¼; v + 249; 1933.

This is a valuable addendum to the author's *La Costituzione Individuale* reviewed in this journal (Volume 9, p. 229). Fuller explanation is given for the choice of measurements taken in relation to their anatomic and physiologic significance. The anthropometric technique, recording and elaboration of data are described in every detail. Of special interest are the tables reproducing the somatic data resulting from the observations of the author and of his students on male and female adults and on adolescents of different age groups. The book is well indexed.

SMOKE AND THE ATMOSPHERE. *Studies from a Factory Town.*

By J. R. Ashworth. Manchester University Press, Manchester. 7s. 6d. net. 8½ x 5⅝; xii + 131; 1933.

This book deals primarily with the methodology of studying atmospheric pollution. The technical details of the construction, calibration and use of apparatus for measuring deposited impurities, particles carried along by the winds, and matter suspended in the air are discussed and the natural and artificial sources of variation are evaluated. Both the experimental work and the statistical analysis of the data collected are carefully done and well presented. There is an index.

TROIS FONDATEURS DE LA MÉDECINE MODERNE: *Pasteur, Lister, Koch. Derniers Écrits. By Élie Metchnikoff. Félix Alcan, Paris.* 15 francs. 7⅜ x 4¾; xi + 195; 1933 (paper).

This is a collection of three articles written by E. Metchnikoff a few years before his death. The first contains brief biographies of Pasteur, Lister and Koch, in which the author's manifest admiration and devotion add much to an understanding of their individual personalities. Of the other two articles, one is on the necessity of giving children adequate sex education and the last is on the significance of "natural" death, entitled *La mort du Papillon du Murier*. Both are well known and often quoted.

MEDICAL WOMEN OF AMERICA. *A Short History of the Pioneer Medical Women of America and of a Few of Their Colleagues in England.*

By Kate Campbell Hurd-Mead. Froben Press, New York. $1.00. 9 x 6; 112; 1933.

This is a very brief history of the invasion of the medical field by women. The author seems to feel the need for bolstering up the case for the woman physician and the tone of the book is decidedly one of defense for women in medicine. There is an appendix consisting of an interesting autobiography of Elizabeth Cushier, one of the early women doctors. The volume concludes with several rather nice photographs of the early medical women. There is an index.

THE AMERICAN FAMILY.
By Ernest R. Groves. J. B. Lippincott Co., Philadelphia. $3.00. 8 x 5⅛; x + 550; 1934.

The author describes and enumerates the economic, social and physiologic factors which may have produced the changes in the social and personal functions of the American family. It is a good review of the many investigations on the different phases of the problem, but no real attempt is made to measure the degree of influence of the above factors or determine the trend of the changes.

ADDENDA TO A BIBLIOGRAPHY OF THE HONOURABLE ROBERT BOYLE.
By J. F. Fulton. Oxford University Press, New York. (Reprinted from the Oxford Bibliographical Society, Proceedings and Papers, Volume III, Part 3, pp. 339–365.) 10 x 7½; iv + 27; 1933 (paper).

This supplement to Fulton's *Bibliography of Boyle*, reviewed in Vol. 8, pp. 366–7, gives a number of editions and variant issues of Boyle's works not recorded in the original bibliography. An advertisement of the sale of Boyle's library and two poetical references to the bust of Boyle in Queen Caroline's Grotto at Richmond are also included. There is an index.

ÉTUDE ET COMMENTAIRES DU LIVRE CURIEUX D'ATHÉNÉE *"Les Deipnosophistes" ou "Banquet des Sages."*
By E. A. Herbodeau. Practical Press, London. 3s. 6d. net. 7¼ x 4¾; 106; no date (paper).

The chef at the Carlton in London writes about the food, drink and table service of the ancient Greeks and Romans, having gleaned his material from Athenaeus' classic *Deipnosophists*.

GUIDING THE ADOLESCENT. *U. S. Department of Labor, Children's Bureau Publication No. 225.*
By D. A. Thom. U. S. Government Printing Office, Washington. 10 cents. 9⅛ x 5⅝; v + 94; 1933 (paper).

LABOR UNDER THE N. R. A.
By Carroll R. Daugherty. Houghton Mifflin Co., Boston. 25 cents per copy (in quantity). 8½ x 5¾; 38; 1934 (paper).

CHILD LABOR. *Facts and Figures. Bureau Publication No. 197.*
By U. S. Department of Labor, Children's Bureau. U. S. Government Printing Office, Washington. 10 cents. 9⅛ x 5⅞; vi + 85; 1933 (paper).

ZOÖLOGY

PLANT PARASITIC NEMATODES AND THE DISEASES THEY CAUSE.
By T. Goodey. E. P. Dutton and Co., New York. $6.75. 8½ x 5½; xx + 306; 1933.

This is a very useful account of the life histories, geographical distributions, and host relationships, of a destructive group of plant parasites, and the appearance of this book will be welcomed by everyone who has to deal with these forms. The system of biometric measurements proposed by the late N. A. Cobb is used in the description of the individual species. For each species there is a separate literature review which sets forth the known information concerning its life history and habits, and a list of the plant species it is known to parasitize. The book is characterized by a careful attention to detail throughout; there are numerous illustrations; the name of the authority follows each Latinized plant and nematode name; bibliographies follow each chapter; and there is a good index. In a foreword Professor R. T. Leiper remarks:

> As knowledge of the morphology and development of a normal, free-living nematode is obviously a most desirable pre-requisite to an understanding of the parasitic species, one may justifiably stigmatize as a calamity both for the parasitologist and the zoologist the universal use in standard text-books of zoology of the unnaturally large and revolting ascarids of domesticated animals as examples of the Phylum *Nemathelmia*. Indeed the traditional teaching in which the nematodes are utilized chiefly as

illustrations of the phenomena of 'degeneration' and 'parasitism' is probably responsible for the lack of appreciation among zoologists generally of a group which displays a unique and highly efficient organization and in which the free-living representatives outnumber those which have adapted themselves remarkably to new environments.

PAPERS FROM TORTUGAS LABORATORY OF CARNEGIE INSTITUTION OF WASHINGTON. *Vol. XXVIII. Carnegie Institution of Washington Publication No. 435.*

Carnegie Institution of Washington, D. C. $1.75 (paper); $2.25 (cloth). 10 x 6⅞; 361 + 47 plates; 1934.

The following papers are included in this volume: On the habits and development of certain Atlantic Synentognathi, by C. M. Breder, Jr.; Physiology and morphology of Porifera exemplified by *Iotrochota birotulata* Higgin, by M. W. de Laubenfels; Lime deposition and the bacteria. I. Estimate of bacterial activity at the Florida Keys, by Haldane Gee; Lime deposition and bacteria. II. Characteristics of aerobic bacteria from the Florida Keys, by Haldane Gee and Catharine B. Feltham; Freezing points of bloods of certain littoral and estuarine animals, by A. S. Pearse; Observations on the parasites and commensals found associated with crustaceans and fishes at Dry Tortugas, Florida, by A. S. Pearse; Inhabitants of certain sponges at Dry Tortugas, by A. S. Pearse; Animals in brackish water ponds and pools at Dry Tortugas, by A. S. Pearse; The *Botryllus* type of ascidian larva, by Caswell Grave; Radium radiation effects on regeneration in *Euratella* Chamberlin, by Raymond G. Stone; The genus *Helicometra* and related trematodes from Tortugas, Florida, by H. W. Manter; Variation in size and in nitrogen requirements during early development of the sea-urchin, *Echinometra lucunter*, by Frederick R. Hayes; Growth of some tissues of *Ptychodera bahamensis* in vitro, by L. R. Cary; The selective action of certain adverse environmental conditions of the hermit crab (*Clibanarius tricolor* Gibbes), by B. W. Kunkel; Two new genera and six new species of Amphipoda from Tortugas, by Clarence R. Shoemaker; Some digenetic trematodes from deep-water fishes of Tortugas, Florida, by H. W. Manter; The mechanism of asymmetry in the Alpheida, by Hugh H. Darby.

While the volume is dated 1934, the greater part of the papers were issued as preprints during 1933.

BUDGERIGARS *in Bush and Aviary.* *By Neville W. Cayley. Angus and Robertson, Sydney.* 7s. 6d. 8⅝ x 5⅞; xvii + 148; 1933.

An abundance of information on the Australian parrot has been collected and pleasantly presented. Budgerigars, good food to the aborigines, are commonly known as parakeets or love-birds. There are chapters on the history of the species, its habits in bush and aviary, housing, feeding, breeding and management, color production and varieties, its training as a talker and pet, and diseases and their treatment.

The appearance of the color varieties in aviaries during the last one hundred years and the manner in which the practical breeder handles these, without definite knowledge of the genetic factors, combine to make the book interesting. We particularly like this in the chapter on diseases:

> Mating Fever. *Symptoms.*—Bird dances and appears highly excited. Spreads out wings and takes a fit somewhat similar to epilepsy.
>
> *Cause.*—Unsatisfied sexual desire. Chiefly prevalent in unmated males desiring hen.
>
> *Treatment.*—Same as epilepsy and spray head with cold water. If possible place in company of hen. Failing that, keep him right out of the line of vision of any mated hens.

TERMITES AND TERMITE CONTROL. *A Report to the Termite Investigations Committee. Editorial Board: Charles A. Kofoid, Editor-in-Chief; S. F. Light; A. C. Horner; Merle Randall; W. B. Herms; Earl E. Bowe. University of California Press, Berkeley.* $5.00. 9¼ x 6; xxv + 734; 1934.

Thirty-four individuals have collaborated to produce this monograph. The work was sponsored by the Termite Investigations Committee which represented mainly

institutions and industries having extensive interests in California. C. A. Kofoid, Professor of Zoology of the University of California, with five others, representing zoology, civil engineering, chemistry, entomology and forestry, formed the Editorial Board. The study is divided into four parts (with fifty-six chapter headings) as follows: (1) Termites and their biology; (2) Chemical investigations; (3) Termite resistivity of woods and building materials; (4) Prevention and repair of termite damage. The volume is extensively illustrated with photographs and drawings. Statistical data are exhibited in eighty-two tables and a large literature list is given. There is no index but the arrangement of the table of contents offsets to a certain extent the omission. The volume will be highly useful to biologists and teachers as well as to architects, engineers, contractors, building inspectors and users of wood. The proceeds derived from the sale of the book will be devoted to further research on these destructive insects.

BUMBLEBEES AND THEIR WAYS.

By Otto E. Plath. The Macmillan Co., New York. $4.00. 8½ x 5¾; xvi + 201; 1934.

The author has been studying and writing about bumblebees for the past twelve years. While he has incorporated in this volume some of his articles which have already appeared in biological journals, these have been thoroughly revised and much condensed. The greater portion of the volume consists of material hitherto unpublished. The life histories and social behavior of thirteen species of true bumblebees (*Bombus*) and four species of parasitic bumblebees (*Psithyrus*) are described in language that the layman can well understand. The author has perfected a technique (described in Chapters X and XI) which will be found highly useful both by the amateur and the more serious student in observing and experimenting with these insects. An appendix gives a detailed account of the more important North American species of bumblebee. The volume is well illustrated, and contains a lengthy bibliography and an index. Professor William Morton Wheeler contributes a foreword.

EXPLORING THE ANIMAL WORLD.

By Charles Elton. George Allen and Unwin, London. 3s. 6d. net. 7¼ x 4¾; 119; 1933.

Mr. Elton always writes interestingly, whether it be for the serious student of science or the amateur. This little book is made up of a series of British broadcast talks given in the spring of 1933, suggesting to the ordinary individual ways in which he can get to know the elaborately organized animal world as it exists in the moors and woods and fields through which he walks. The six chapters treat of how to look for animals; their manner of working and resting; their professions; making a survey of one particular sector of the animal world; animal life at night; sanctuaries for wild life and the part that ecology can play in making them successful; plagues of animals, etc. At the end of the book is given a brief literature list and a brief section on *How to survey woodland birds*. The book is illustrated by several woodcuts by Nora S. Unwin. There is no index.

MAULED BY A TIGER. *Encounters in the Indian Jungles.*

By Arthur W. Strachan. The Moray Press, Edinburgh and London. 12s. 6d. 8½ x 5½; xi + 279 + 16 plates; 1933.

Again we are impressed with the heavy moral responsibility there attaches to being an Englishman. This time it is in connection with pursuing and killing wounded animals, even at considerable risk to life and limb. In fact, that is how the author came to be mauled.

It does not make the reading any easier to have a liberal use of native terms which have to be followed by their English equivalents. But even so this is an interesting account of what actually happens where tigers live and steal cattle and have to be killed. There is little of the "sport for sport's sake" attitude; it is mostly

business and rather casual with no elaborate preparations nor hordes of servants. The pictures are delightful. Most of them are reproductions of the author's miniatures on ivory.

MAN-KILLERS I HAVE KNOWN.

By A. J. Siggins. Wright and Brown, London. 15 shillings net. $8\frac{7}{8}$ x $5\frac{3}{4}$; v + 312; [no date].

Readers of *Shooting with Rifle and Camera* will not find this volume as interesting as the other. The author describes mainly the hunt for lions or leopards that have turned "man-killers." There are very thrilling incidents but every tale is recited in almost identical manner so that towards the end they lose interest. Those relating to crocodiles are better written and more dramatic. Vague allusions are made to human "man-killers" but very little actually reported except for a few incidents of native guerrillas and one or two alleged examples of Portuguese maltreatment of the natives. For the latter the author demonstrates much sympathy and even respect for their superstitions.

THE ELEMENTS OF EXPERIMENTAL EMBRYOLOGY.

By Julian S. Huxley and G. R. De Beer. The University Press, Cambridge; The Macmillan Co., New York. $7.00 (U. S. A.). $8\frac{1}{2}$ x $5\frac{1}{2}$; xiii + 514; 1934.

Huxley and de Beer have written an excellent account of experimental embryology, chiefly based on amphibian development in the prefunctional stage, in which emphasis is laid on relative growth as the principle by which determination and differentiation appear in an embryo derived from a non-diversified egg. There is a large amount of data in the literature derived from the experimental analysis of development available for such a treatment and it has been used to good advantage. There is a large number of good illustrations, most of them taken from research journals. The bibliography has been arranged to serve as an author index and there is a separate subject index.

HANDBOOK OF FROGS AND TOADS. *The Frogs and Toads of the United States and Canada.*

By Anna A. Wright and Albert H. Wright. The Comstock Publishing Co., Ithaca, N. Y. $2.50. $7\frac{3}{4}$ x $5\frac{3}{8}$; xi + 231; 1933.

This is an excellent volume for the herpetologist, ecologist, and field-naturalist. It describes clearly and in detail the frogs and toads of the United States and Canada, and gives much general ecological information about their range, habitat, and reproductive habits. The brochure is profusely illustrated with photographs and diagrams and is sensibly bound for a handbook. A good bibliography is appended.

THE CHINESE MEDICAL JOURNAL. *Vol. XLVII, Nos. 11 and 12. Professor Fülleborn Memorial. Parasitology Number.*

Peiping Union Medical College, Peiping. $9\frac{7}{8}$ x $6\frac{7}{8}$; 402; 1933 (paper).

A special parasitology number of the *Chinese Medical Journal* prepared as a memorial to Professor Dr. F. Fülleborn, former Director of the Institute of Tropical Diseases at Hamburg. In this issue 362 pages are given to twenty-eight articles which deal with histopathology, morphology of parasites, and various biological relationships of parasites in human diseases. The contributions are all published in English and are well illustrated, and withal give an excellent idea of the status of parasitological studies in China. Some nineteen pages are given to editorials, notes, and news items. The issue also carries the index for the 1933 volume of the *Journal*.

LA MÉTHODE LOEWENSTEIN. *Appliquée au Sang des Bovidés. Acta Veterinaria Neerlandica, Tome I, Fasc. 3.*

By C. F. van Oijen. J. v. Boekhoven, Utrecht. $9\frac{1}{2}$ x $6\frac{1}{4}$; 64; 1934 (paper).

A report of the work of the author and his collaborators in the Faculty of Veterinary Medicine at the University of Utrecht on tuberculous bacillemia in animals, following the Loewenstein technique. The results showed that tubercle bacilli were detected:

a. in the venous blood, leaving a tuberculous organ (e.g. the udder of the cow),
b. in the blood extracted from the Vena jugularis in animals after experimental infection,
c. in the blood extracted from the heart of those animals and in one case of spontaneous tuberculosis,
d. in the meat juice from several animals.

THE CULT OF THE GOLDFISH.
By T. C. Roughley. Angus and Robertson, Sydney. 6 shillings. 8¾ x 5¾; xiii + 146; 1933.

This is a book destined for a warm reception by naturalists and the fish-fancier clan. It gives information, calmly and interestingly, about the numerous varieties of goldfish and presents well the rather surprising amount of technical knowledge required for their optimal care. Certain illustrations add to the value of the book.

LA VIE DE LA MANTE RELIGIEUSE.
By Léon Binet. Vigot Frères, Paris. 20 francs (paper); 40 francs (de luxe edition). 9¾ x 7¾; 92; 1931.

A brief, but good, account of the life history of the fascinating Praying Mantis (*Mantis religiosa*). It is provided with illustrations and a bibliography of six pages. We were sorry to note several typographical errors, especially the one in line 1 of the text where the Christian name of the insect is given as *reliogisa*.

A MALARIA-LIKE DISEASE OF DUCKS *Caused by Leucocytozoon anatis Wickware. University of Michigan, School of Forestry and Conservation Bulletin No. 4.*
By Earl C. O'Roke. University of Michigan Press, Ann Arbor. 25 cents. 9 x 6; 44 + 5 plates; 1934 (paper).

A report on three years of study of a disease that attacks both tame and wild ducks. The stages in the life history of the protozoan parasite, *Leucocytozoon anatis* Wickware, are described in detail, supplemented by plates made from cytological preparations of the organism. The disseminating host is the common black fly, *Simulium venustum*. Practical methods of control are outlined.

LES PAGURES OU BERNARDS L'ERMITE. (*Un Exemple d'Adaptation*). *Actualités Scientifiques et Industrielles 101. Exposés de Biologie Zoologique.*
By Charles Pérez. Hermann et Cie, Paris. 9 francs. 10 x 6¼; 33; 1934 (paper).

A highly interesting account of the hermit crab and the changes of its anatomical structure for adapting it to making use of shells and sponges as habitat and protection. The illustrations are excellent.

STREIFZÜGE DURCH DIE UMWELTEN VON TIEREN UND MENSCHEN. *Ein Bilderbuch unsichtbarer Welten.*
By J. Baron Uexküll and G. Kriszat. Julius Springer, Berlin. 4.80 marks. 7⅛ x 4⅝; x + 102; 1934.

Curious and interesting pictures and descriptions of the environment of animals.

THE MORPHOLOGY OF HAPTOPHRYA MICHIGANENSIS WOODHEAD, AN ASTOMATOUS CILIATE FROM THE INTESTINAL TRACT OF HEMIDACTYLIUM SCUTATUM (SCHLEGEL). *University of California Publications in Zoology, Vol. 39, No. 12.*
By Mildred Bush. University of California Press, Berkeley. 10¼ x 6¾; 26 + 3 plates; 1934 (paper).

A NEW RACE OF CHIPMUNK FROM THE GREAT BASIN OF WESTERN UNITED STATES. *University of California Publications in Zoology, Vol. 40, No. 6.*
By E. Raymond Hall and Donald M. Hatfield. University of California Press, Berkeley. 10¼ x 6¾; 5; 1934 (paper).

PUBLICATIONS OF THE UNIVERSITY OF OKLAHOMA BIOLOGICAL SURVEY. *Volume V. No. 1. Howard Atwood Kelly, by A. I. Ortenburger and Roberta D. Ortenburger. No. 2. The Decapod Crustaceans of Oklahoma, by E. P. Creaser and A. I. Ortenburger. No. 3. The Ecology of the Western Oklahoma Salt Plains, by A. I. Ortenburger and R. D. Bird. No. 4. Notes on the Occurrence of Mammals in the Regions Adjacent to the Salt Plains of Northwestern Oklahoma, by H. H. T. Jackson and H. E. Warfel.*

University of Oklahoma Press, Norman. $1.00. 9 x 6; 87; 1933 (paper).

BOTANY

PLANTS AND HUMAN ECONOMICS.

By Ronald Good. The University Press, Cambridge; The Macmillan Co., New York. $1.75. 7¼ x 4⅞; xii + 202 + 8 maps; 1933.

A new approach to the study of botany. The author aims to make the science of plants something more than a means of mental discipline. Botanical facts form the basis of the text but the emphasis is put on the implications of the science from a humanistic and economic point of view. In order that the reader may more readily grasp the general aspects of the book it seems best to list the chapter headings. An introductory chapter deals with foodstuffs and raw industrial materials, then follow sections on: The nature and sources of food; The life of the green plant; Factors limiting agricultural production; Science and agriculture; Cereals and pulses; Vegetables: salad plants: fruits; Beverages: sugar and starch: oils and fats: spices; Timber, coal and petroleum; Rubber: resins, balsams and gums: tans and dyes: fibres; Alcohol: drugs: fodders: miscellaneous; The useful products of the lower plants: Concluding notes on vegetable products; The economic botany of Great Britain. A series of maps show the distribution of foodstuffs and plant products. There is also included an appendix giving scientific and English names of common plants, a selected reference list and an index.

AMERICAN TOBACCO TYPES, USES AND MARKETS.

By Charles E. Gage. U. S. Government Printing Office, Washington. 20 cents. 9⅛ x 5⅝; 88 + folding map; 1933 (paper).

This pamphlet deals with one of the most interesting of the industries concerned with agricultural products. It is interesting not only because of the stringent climatic and edaphic limitations that confront the tobacco grower but because of the peculiar preferences of the buying public, and the users of tobacco are scattered over enough continents to have developed some curious tastes. The treatment is that of the agricultural economist, primarily; there are numerous detailed statistical tables of crop production in the various tobacco producing regions of this country, together with notes on the amount of caution necessary in interpreting them, and brief descriptions of the cultural practices prevailing in different sections. Most interesting of the statistical data, perhaps, are a table showing the annual consumption of tobacco products in this country since 1880 and a large map of the tobacco growing regions. There is a large amount of interesting information about the human foibles that have to be catered to, and, in some cases, explanations as to how apparently arbitrary preferences of long standing have arisen.

A SHORT HISTORY OF GARDENS.

By H. N. Wethered. Methuen and Co., London. 12s. 6d. net. 7½ x 5⅛; xv. + 323; 1933.

Mr. Wethered has, one might say, done the history of gardens up good and brown. One is interested to learn how the geographical, climatic, and national temperament of a land and its people affect its gardens. The story begins in Egypt, and is traced through Homer, the two Plinys, the fantastic gardens of Byzantium and Baghdad, where trees of gold bore fruits of precious gems, the monastery gardens of the Middle Ages, and the Renaissance gardens of Italy to Versailles and Hampton Court, and thence through Capability Brown to the modern garden, where our love of athletics is reflected in the inclu-

sion of the tennis court and swimming pool. The author has given us a very readable history which will interest the student of the origin of ideas as well as the lover of gardens. There is an index.

BERGEY'S MANUAL OF DETERMINATIVE BACTERIOLOGY. *A Key for the Identification of Organisms of the Class Schizomycetes. Fourth Edition.*

By David H. Bergey. Assisted by a Committee of the Society of American Bacteriologists: Robert S. Breed, Frank M. Huntoon, Bernard W. Hammer, E. G. D. Murray, Francis G. Harrison. With an Index by Robert S. Breed. The Williams & Wilkins Co., Baltimore. $6.00. 9 x 6; xvi + 664; 1934.

Each new edition of this widely used manual is larger than its predecessor by about 100 pages. In this fourth edition

Two new genera have been recognized in Tribe *Bacteriae*, namely Genus *Brucella* and Genus *Listerella*. Genus *Pfeifferella* has been combined with Genus *Actinobacillus*.

Information was available for the amplification of the descriptions of species of the following genera: *Leuconostoc*, *Propionibacterium*, *Bacterioides*, and Order *Myxobacteriales*.

Descriptions of about 50 new species have been included while several organisms have been omitted as distinct species and the names recognized as synonyms for other species.

POST-LOGGING DECADENCE IN NORTHERN HARDWOODS. *University of Michigan, School of Forestry and Conservation Bulletin No. 3.*

By Ralph C. Hall. University of Michigan Press, Ann Arbor. 25 cents. 9 x 6; 66; 1933 (paper).

A study contributing to better management of our northern hardwood forests. The author shows that the bronze birch borer is not a primary pest of the forest birch, and that post-logging decadence is conditioned by many physical, physiographic and biotic factors. The intensity of any cutting must be conditioned by the general character of the forest and not by mere size utility of the trees if injury is to be avoided. The ecological data are treated statistically, and in a brief appendix the constants used are defined, following the methods popularized by Harris.

ÉTUDE ÉCOLOGIQUE ET PHYTOSOCIOLOGIQUE DE L'ASSOCIATION À BRACHYPODIUM RAMOSUM ET PHLOMIS LYCHNITIS DES GARIGUES LANGUEDOCIENNES. *Communication No. 18.*

By F. R. Bharucha. Station Internationale de Géobotanique Méditerranéenne et Alpine, Montpellier. 9¼ x 6½; 132; 1932 (paper).

A careful and intensive ecological survey of the *garigue* in the vicinity of Montpellier was made under the direction of Professor Braun-Blanquet, and the results presented here are reprinted from the *Beihefte zum botanischen Centralblatt*, 50: 247–379, 1933. This association appears to be one of the last stages of degeneration of oak forest under the influence of cutting and burning. The soil, of course, has been greatly influenced by these disturbances, and careful attention was paid to its characteristics. Almost every method now in use by plant ecologists was employed and the whole investigation is characterized by thoroughness and completeness.

CULINARY HERBS AND CONDIMENTS.

By M. Grieve. Harcourt, Brace and Co., New York. $2.00. 7⅜ x 5; v + 209; 1934.

A book highly useful to all those interested in the art of cookery. It contains a complete catalogue of all the culinary herbs with descriptions and details concerning their cultivation. Many recipes are given to illustrate the uses of the herbs. There is a special section giving recipes for home-made wines, herbal beers and other herbal beverages, a section on condiments and culinary oils and one on cooking utensils. The volume is indexed.

GARDEN FLOWERS IN COLOR. *A Picture Cyclopedia of Flowers.*

By G. A. Stevens. The Macmillan Co., New York. $3.75. 9 x 6; 320; 1934.

This is an attractive assemblage of colored illustrations of garden flowers and ornamentals. The pictures of each type are accompanied by a brief note on habits of growth and flowering, and there are many suggestions on the best use in planting. It should be most useful in planning seasonal color combinations for the garden. Reference is facilitated by an index that gives both botanical and vernacular names.

RECENT ADVANCES IN PLANT PHYSIOLOGY. *Second Edition.*

By E. C. Barton-Wright. P. Blakiston's Son and Co., Philadelphia. $4.00 net. 7⅞ x 5¼; x + 341; 1933.

This is the second edition of a textbook for advanced students of plant physiology dealing with recent advances in fields in which research is most active at present. Only minor changes appear to have been made during revision and most of the literature references are to articles in English. There is an excellent index.

SILVA FENNICA 27. *Der Holzmangel in Finnland von 1809, seine Gründe und die Massregeln zu seiner Bekämpfung.*

By Martti Hertz. Society of Forestry in Suomi (Finland), Helsinki. 9⅜ x 6⅝; 66; 1933 (paper).

SILVA FENNICA 28. *The Pulpwood Question. Society of Forestry in Suomi (Finland), Helsinki.* 9⅜ x 6⅝, 142; 1933 (paper).

SILVA FENNICA 29. *Über tägliche Herstellungsmengen von Papierholz in Perä-Pohjola in den verschiedenen Jahreszeiten.*

By Einar Maliniemi. Society of Forestry in Suomi (Finland), Helsinki. 9⅜ x 6⅝; 14; 1933 (paper).

SILVA FENNICA 30. *Die waldbeutschnische Kontrolle der Waldwirtschaft.*

By V. Lihtonen. Society of Forestry in Suomi (Finland), Helsinki. 9⅜ x 6⅝; 52; 1933 (paper).

SILVA FENNICA 31. *The Small Timber Problem.*

Society of Forestry in Suomi (Finland), Helsinki. 9⅜ x 6⅝; 219; 1933 (paper).

SILVA FENNICA 32. *Über die Vegetation des Naturparks von Hiisjävi.*

By Alfred Brandt. Society of Forestry in Suomi (Finland), Helsinki. 9⅜ x 6⅝; 1933 (paper).

SILVA FENNICA 33. *Über die besondere Stellung des Waldarbeiters im Arbeitsrecht.*

By Mauno Forsström. Society of Forestry in Suomi (Finland), Helsinki. 9⅜ x 6⅝; 30; 1933 (paper).

ACTA FORESTALIA FENNICA 39.

Publications of the Society of Forestry in Suomi (Finland), Helsinki. 9½ x 6⅝; 1933.

MORPHOLOGY

THE CORTICAL LOCALISATION OF CEREBRAL FUNCTION.

By J. Shaw Bolton. Oliver and Boyd, Edinburgh. 6 shillings. 9¾ x 7⅜; 23 + 12 plates; 1933 (paper).

In 1832 Mr. William Ramsay Henderson died in Edinburgh leaving a trust fund for "the advancement and diffusion of the Science of Phrenology." Although Phrenology as Mr. Henderson probably understood the term is long since dead the problem of the relation between cerebral structure and function is still very much alive. In this lecture under the Henderson Trust Professor Bolton deals with this relation in the neopallium, which "provides for the individual motor educability which is the peculiar and paramount characteristic of the mammalia compared with the lower forms of animal life." He traces briefly its phylogenetic and ontogenetic development and correlates the gross and microscopic structural defects with clinical symptoms.

The prefrontal cortex is late in evolution, high in complexity, and low in stability. The mental disease so common in man is the natural consequence of the over-stepping of the limits of capability and of durability, and must be regarded as the penalty still paid by man for the gift of volition, and as evidence of the relatively recent evolution, in geological time, of this capability.

THE ANATOMY OF THE RHESUS MONKEY (*Macaca mulatta*).

By T. H. Bast, Kermit Christensen, Harold Cummins, Frederick D. Geist, Carl G. Hartman, Marion Hines, A. Brazier Howell, Ernst Huber, Albert Kuntz, S. L. Leonard, P. Lineback, John A. Marshall, Gerrit S. Miller, Jr., Ruth A. Miller, Adolph H. Schultz, T. D. Stewart, William J. Straus, Jr., W. E. Sullivan, Geo. B. Wislocki. Illustrated by Benjamin Kopel. Edited by Carl G. Hartman and William L. Straus, Jr. The Williams and Wilkins Co., Baltimore. $6.00. 9 x 6; ix + 383; 1933.

Representing largely the individual researches of nineteen collaborators, this work furnishes a greatly needed systematic handbook of the anatomy of one of the most important laboratory animals. A chapter is devoted to each anatomical system and the senior editor contributes a very valuable appendix on the housing and care of monkeys. Without exception each section is carefully and concisely written; the illustrations by Benjamin Kopel are simply and clearly executed; and a complete index rounds out the volume. It is certain that the editors' hope ". . . . that the book attains the immediate object of affording a useful description of the rhesus monkey for research workers . . . ." will be realized.

INTRODUCTION TO CYTOLOGY. *Third Edition.*

By Lester W. Sharp. McGraw-Hill Book Co., New York. $5.00. 9 x 5¾; xiv + 567; 1934.

This edition has been altered to improve "its adaptability to the needs of students with comparatively little experience in the special field of cytology, without, however, making it an elementary treatise. To this end much of the material has been rearranged, the treatment of many points has been simplified, and certain borderline topics have been omitted altogether." Most of the citations to literature have been transferred to footnotes. The bibliography has been completely revised and forty new illustrations added.

HUMAN EMBRYOLOGY AND MORPHOLOGY. *Fifth Edition.*

By Sir Arthur Keith. William Wood and Co., Baltimore. $10.00. 9 x 5¾; viii + 558; 1933.

The last edition of this well-known textbook appeared in 1923. The present edition has been completely revised and reset. Two new chapters—IV on physiological and pathological embryology, and XXI on organs of digestion (continued)—have been added, while much new material on experimental embryology has been included in the various chapters. References to recent publications have been collected at the end of each chapter instead of in footnotes as in previous editions.

THE STUDY OF ANATOMY. *Written for the Medical Student. Second Edition, Rewritten and Enlarged.*

By S. E. Whitnall. William Wood and Co., Baltimore. $1.50. 7¼ x 4⅞; v + 93; 1933.

Good advice to medical students about many things—necessity of clean hands as well as how to study anatomy. Committed to the thesis that "form is determined by function" the book outlines the way anatomy should be learned. It is not in any sense an anatomy laboratory guide, but it is full of sensible advice and is very interesting reading. There is a bibliography of 122 titles.

PHYSIOLOGY AND PATHOLOGY

RÔLE DU SYSTÈME NERVEUX ET DES FACTEURS BIOLOGIQUES ET PSYCHIQUES DANS L'IMMUNITÉ.

By S. Métalnikov. Masson et Cie, Paris. 28 francs. 9¾ x 6½; 166; 1934 (paper).

The author summarizes the results of his experiments showing the importance of the nervous system in immunity. The most interesting of these was that of conditioning guinea pigs and rabbits so that without antigen injection but only by auditory or tactile stimulation the usual leukocyte reaction was obtained and for

the expected length of time. He reports not only leukocytosis but, for the guinea pig at least, the usual formula of increase in polynuclears, followed by that of mononuclears. These observations, which may be justly doubted, have not been always confirmed by other workers. The failures are attributed by the author to lack of precautions in the conditioning of the animals. He offers as critical proof a series of experiments in which, accompanied by an external stimulus, he inoculated guinea pigs with an emulsion of heated staphylococci twenty times. Twenty days following the last injection some of the animals were given the external stimulation and immediately afterwards all were injected with a mortal dose of *B. cholerae*. Those that had not received the external stimulus died within twenty-four hours, the others are still alive! [Reginald the Office Boy wants to know whether the tune played was "Smoke Gets in Your Eyes" or the "Marseillaise." He says it might make a difference.]

Such astounding results deserve further experimentation by less sanguine observers. Apparently, from the author's description, the experiments were as well conducted and controlled as in most laboratories.

There is a bibliography of 121 titles.

THE BRAIN AND ITS MECHANISM.

By Sir Charles Sherrington. The Macmillan Co., New York; The University Press, Cambridge. 50 cents (U. S. A.). 7⅞ x 5; 35; 1933 (paper).

In this Rede lecture the distinguished neurologist gives a brief account of the mechanism of the nervous system and a discussion of the mind-body problem. He concludes that

> we have to regard the relation of mind to brain as still not merely unsolved but still devoid of a basis for its very beginning. I am not a defeatist, for I would urge active pursuit of the enquiry. Even on the old line of deciphering principles of action of the brain in its management of muscle in the hope of clues to its ways of working in regard to mind. Not that any reflex principle seems applicable to mental activity. The reflex implies an end-result at which the nerve-process having shot its bolt stops and goes no further. But attempted correlation of mind with brain activity indicates for the latter through-line processes which are in no sense end-effects at all. Nevertheless, there are broad analogies. May we not think that anyhow there is no transmission from a, so to say, mental power-head, but a subtle spread of action over an unstable train, its strength at any point resting on the stability at that point? A ghost may be a very weak visual stimulus and yet release a large mental reaction.

SOME FACTORS IN THE LOCALISATION OF DISEASE IN THE BODY.

By Harold Burrows. William Wood and Co., Baltimore. $5.25. 8½ x 5½; xi + 299; 1932.

Professor Burrows here attempts to bring together a large amount of scattered information on the physiology of the localisation of disease processes. The three parts of the book deal respectively with: (a) localisation of colloidal matter, bacteria, and cells from the blood stream; (b) changes in the permeability of the capillary endothelium, transport of matter from the blood stream to the tissues, and the retention of matter by inflamed tissue; and (c) a general discussion of the inflammatory barrier and endothelial permeability. Three significant conclusions are drawn concerning the conditions which are required for localisation of many blood borne diseases:

1. An abnormal permeability of the walls of the small blood vessels.

2. The presence of forces which will transport the noxious agents through the endothelial cytoplasm.

3. The retention of noxious agents in the tissues under the influence of inflammation.

The value of the book is enhanced by a bibliography of over 400 references, and an index.

CARACTERISTICAS REGIONALES DE LA PATOLOGIA DIGESTIVA DE ANDALUCIA OCCIDENTAL Y EXTREMADURA.

By José M.ª González Galvan. Dr. José M.ª González Galvan, Albareda, 30, Sevilla, Spain. 9⅝ x 6⅞; 44; 1933 (paper).

This is a study of the sex, dietary habits,

general constitution and mode of living of 3754 patients suffering from gastro-intestinal diseases. From these observations the author attempts to construct "personalities" which he considers associated with the different diseases and in a way characteristic of Western Andalusia and Estremadura. He describes: the "ulcer personality," usually found in males, hard working and of careless dietary habits; the "gastritic," more frequent in males who are great imbibers of wine; the "neurotic" found generally in neurotic females; the "ptosic," more common in women of flaccid physique, either virgin or too fertile multiparous; etc. It is not evident that these "personalities" are exclusively characteristic of that region.

The statistical data of disease incidence, though interesting, cannot be used for comparison because incomplete. Noticeable is the small percentage of malignancies (diagnosed in about 3 per cent of the patients), but since the age distribution is not given the significance cannot be judged.

PHYSIOLOGY OF MUSCULAR ACTIVITY.

By Edward C. Schneider. W. B. Saunders Co., Philadelphia. $2.75 net. 7½ x 5⅛; 401; 1933.

Within recent years there has been an increasing number of physiological studies on the effects of exercise, some of them being comparisons of athletes and non-athletes or observations on a group of men during a period of training, while other investigations have been made on athletes participating in the Olympic games and other major sporting events, particularly the more gruelling events like Marathon runs and rowing races. It is interesting to note that a trained man can perform a given amount of work with a smaller consumption of oxygen and with a greater mechanical efficiency than an untrained man, quite apart from the superiority in coördination to be expected from the athlete. Many of these studies have been sound contributions to physiology and they have served to supplement laboratory experiments in a very useful way. This book not only presents the results of work of this kind in a very nice way, but it also supplies the background in physiology necessary for an appreciation of the experiments, and it should present no great difficulties for anyone with a college course in physiology.

There is a good index and an extensive bibliography.

L'ÉVOLUTION DE LA LUTTE CONTRE LA SYPHILIS. *Un Bilan de 25 Ans. Nancy 1907–1932.*

By Louis Spillmann. Masson et Cie, Paris. 30 francs. 9 x 5⅝; vii + 292; 1933 (paper).

Combining true missionary zeal with a sound realistic attitude, Dr. Spillmann has for twenty-five years led a campaign to check the propagation of syphilis in the Moselle district of France. In this volume he presents his methods and objectives. The means he has used differ from those generally adopted by the health boards in our more progressive cities in two particulars worthy of mention. One is the extensive use of propaganda—personal appearances, radio talks, pamphlets, books, etc., to inform the youths, of the working class especially, of the signs, symptoms and mode of progression of syphilis, emphasizing the necessity and benefits of early treatment. The other remarkable feature of his organization is the success in tracing and eliminating sources of infection. Like most physicians he realizes the futility of attacking prostitution and therefore limits himself to attempts to maintain it under strict medical control.

This book should be of encouragement to the syphilologists and others who are seeking a solution of this important problem in public health.

CLINICAL STUDIES ON THE PHYSIOLOGY OF THE EYE.

By J. Grandson Byrne. H. K. Lewis and Co., London. 10s. 6d. net. 8½ x 5½; x + 144; 1934.

This volume of some 140 pages is designed to aid clinicians in the practical applica-

tion of the author's experimental work published under the title *Studies on the Physiology of the Eye*. The conclusions from the earlier publication are reiterated. Considerable space is given to diagnostic case histories supplemented by careful descriptions of the eye reactions, photographic reproductions and diagrams. The author shows how the "pseudo-paradoxical" phenomenon may be useful in distinguishing between malingerers and true sufferers from injury. And he also develops the thesis that study of the pupillary responses should be made an integral part of all routine physical examination. Although the book may not appeal as a facile manual, it is full of important clinical, experimental, and practical knowledge directly applicable in diagnostic technique. There are bibliographies at the end of several chapters, and an index.

VETERINARY HYGIENE. *Second Edition.* *By R. G. Linton. W. Green and Son, London.* 21 shillings. 9⅝ x 6; xix + 472; 1934.

This book first appeared in 1921. It was written for the veterinary student, the practitioner and others concerned with the well-being of animals. The second edition has been thoroughly revised and extended. The section on Sanitary Law, appearing in the first edition, has been omitted; also the greater part of the section dealing with preventable diseases, only an account of those notifiable in Great Britain being retained. A section on the housing of poultry and an account of the more common diseases has been added, also sections on dips and dipping and on construction of dog kennels. That part treating of the processes involved in sewage purification has been extended. The volume contains numerous diagrams and photographs, statistical data and occasional references to literature. It is indexed.

A SHORT HISTORY OF THE EPIDEMIC INFECTIOUS DISEASES. *By E. W. Goodall. John Bale, Sons and Danielsson, London.* 3s. 6d. net. 7⅛ x 4¾; 113; 1934.

A short history of one of the more specialized fields of science might be presumed to be either a carefully selected group of dramatic incidents in the development of the discipline or a compact compendium of dates, names and facts. Good books of the former kind, like Sir Michael Foster's *The History of Physiology*, are rare and it is the privilege of few to write them. Quite certainly Doctor Goodall has not succeeded. Beginning with a short chapter on the nature of infection and a brief review of the notable epidemics, the author summarizes rapidly pertinent facts in the history of plague, small-pox, chicken-pox, measles, and so on, and closes with a short note on epidemiology and prevention. The book is carefully and painstakingly, but not very interestingly, written.

COLD SPRING HARBOR SYMPOSIA ON QUANTITATIVE BIOLOGY. *Volume I.* *The Biological Laboratory, Cold Spring Harbor, Long Island, N. Y.* $2.90. 10¾ x 7¾; xi + 239; 1933.

The twenty-eight short papers in this volume were read by invitation at the Cold Spring Harbor Symposium on Quantitative Biology in July 1933, and are characterized by their mathematical approach to the biological problems concerned. For the most part the subjects discussed can be grouped under the headings of biocolloids, electrophysiology, and oxidation-reduction phenomena in living systems, and they are presented in the form of lectures to advanced students of the subject. The papers are followed by short bibliographies and by digests of the discussion which followed their reading. This is intended to be the first of a series of annual symposia.

VERSUCHE EINER DEUTUNG DER PATHOGENESE DER SKELETTVERÄNDERUNGEN BEI CHONDRODYSTROPHIA FOETALIS (KAUFMANN). *Acta Pathologica et Microbiologica Scandinavica, Supplementum 15.*

By Åke Wilton. Levin and Munksgaard, Copenhagen. Dan. Cr. 10. 10 x 6½; 168; 1933 (paper).

The author of this excellent study of *Chondrodystrophia foetalis* concludes that the etiology of this disease is the same as that of rickets, except that it attacks the individual in intra-uterine, rather than extra-uterine, life. The same biological disturbances—deficiency of vitamines, hormones or organic salts, or lack of balance among them—are involved in both diseases. The author suggests that the name *Chondrodystrophia foetalis* be replaced by the older and more correct designation *Rachitis foetalis*. A five-page bibliography is appended.

A Short History of Physiology.

By K. J. Franklin. John Bale, Sons and Danielsson, London. 3s. 6d. net. 7⅛ x 4¾; vii + 122; 1933.

This is one of a series of histories of the medical sciences under the editorship of Arnold and Maurice Sorsby. After an account of the Greek physiologists, chapters are devoted to Leonardo da Vinci and Vesalius. The work in the sixteenth century on the pulmonary vascular system and the valves of veins is then traced, leading up to Harvey's demonstration of the circulation of the blood. With the quickened pace of physiological research in the centuries since Harvey, it is inevitable that a short history should record the work of this period in less detail. In his preface the author acknowledges his chief sources. There is an index of names.

Contagious Diseases. *What They Are and How to Deal With Them.*

By W. W. Bauer. Alfred A. Knopf, New York. $2.00 net. 7⅛ x 5; xiv + 218; 1934.

Grandmother's "doctor book" gone modern! And really modern and up-to-date. The author furnishes the mother of a family with good, sound, yet simple advice about some of the things a public health department should do and what she should do about contagious diseases. The section on immunity is very good. There are separate chapters on the different diseases as well as practical suggestions on the care of the sick. There is a glossary of terms and an index.

Hydrologie Expérimentale.

By Maurice Villaret and L. Justin-Besançon. Masson et Cie, Paris. 50 francs. 9⅞ x 6⅜; 271; 1933 (paper).

A study of mineral waters from European spas as they affect the contraction of isolated smooth muscle fibers. There are some 120 kymographic tracings which clearly show change in tonus, rhythm, and other effects such as antagonisms to stimulating chemicals. The author reports constant reactions for a given water with a fixed technique. However, he reserves any broad clinical or biological conclusions, and offers his data as descriptive material in characterization of the waters.

Our Mysterious Life Glands *and How They Affect Us. A Popular Treatise on Our Glands and Their Secretions—What They Do to Us, How They Affect Our Health, Growth, Appearance, Temper, Mentality, and Character, Including The Vitamins.*

By William J. Robinson. Eugenics Publishing Co., New York. $2.50. 8¼ x 5½; xx + 291; 1934.

A volume by a prolific writer presenting general knowledge about the relation of our endocrines to our well-being. The book has the attribute of text organization and to some readers it will be interesting—possibly even exciting. Biologists (not medicoes) *may* take exception to the following statement:

> . . . . With all due respect to our relations—mice, rats, rabbits, guinea pigs, capons, and tadpoles—sexuality is so different in man than it is in other species, that great as are the similarities, the differences are still greater.

LA SYPHILIS EXPÉRIMENTALE. *Étude Critique et Nouvelles Recherches.*

By P. Gastinel and R. Pulvenis. Masson et Cie, Paris. 45 francs. 10 x 6½; 244; 1934 (paper).

A comprehensive study on experimental syphilis with particular reference to the authors' own work on rabbits. Of major interest to the biologist and clinician appear the observations on the several types of lesions, the different organic reactions to infection, the various factors which modify the evolution of the disease, the nature and mechanism of immunity and its relation to allergic phenomena. The authors attach great importance to the Meinicke test and offer considerable evidence to prove its sensitivity and validity.

THE MODIFICATION OF VESTIBULAR NYSTAGMUS BY MEANS OF REPEATED ELICITATION. *Comparative Psychology Monographs, Vol. 9, No. 5, Serial No. 45.*

By O. H. Mowrer. The Johns Hopkins Press, Baltimore. 75 cents. 10 x 6⅞; 48; 1934 (paper).

Reduction of post-rotation nystagmus takes place when pigeons are subjected to repeated rotations for a certain length of time and in given conditions. The merit of this report consists in showing that this phenomenon is markedly evident when the animals are subjected to bodily rotations with vision excluded. The mechanism underlying this "habituation" is unknown, but there are various theories which the author reviews. The experiments have been well conducted, though on relatively few animals. There is a bibliography of 65 titles.

TRAITÉ DE PHYSIOLOGIE NORMALE ET PATHOLOGIQUE. *Tome V: Respiration.*

By Léon Binet, L. Dautrebande, H. Hermann, C. Heymans, Pierre Thomas. Published under the direction of G.-H. Roger and Léon Binet. Masson et Cie, Paris. 80 francs (paper); 100 francs (cloth). 9¾ x 6⅝; xvi + 474; 1934.

In this volume of the comprehensive eleven-volume French text book of physiology L. Binet contributes chapters on the histophysiology and biochemistry of the lung, the internal functions of the lung, and physio-pathological studies of various respiratory disturbances; P. Thomas contributes a biochemical study of respiration; L. Dautrebande writes of the gaseous exchanges; and H. Hermann of basal metabolism. The high standard set in earlier volumes is well maintained.

PHYSIOPATHOLOGIE DES SYNDROMES ENDOCRINIENS.

By Noël Fiessinger. Masson et Cie, Paris. 40 francs. 9⅛ x 6¼; 317; 1933 (paper).

A concise but thorough review of the most important studies on the physiology and pathology of the endocrine glands and of the other organs which also secrete internally. The authority of the writer, combined with the clarity of style, makes this an excellent textbook. The various experimental procedures from which the fundamental physiologic facts have been derived are described in detail. There is no index.

L'EXCITATION ELECTRIQUE DES TISSUS. *Essai d'Interprétation Physique.*

By A.-M. Monnier. Hermann et Cie, Paris. 85 francs. 10 x 6½; xvi + 326; 1934 (paper).

This highly technical study on the electric stimulation of tissues is based on the work and hypotheses of Lapicque. The author attempts to give a purely physical interpretation of these phenomena and arrives at a general equation that expresses the different physiologic manifestations as deriving from one electrophysical system. Lastly he dwells at length on the significance of chronaxie and on its importance as unit of measure of electric excitation. There is a bibliography of 297 titles.

POLARISATION ET DÉPOLARISATION CELLULAIRES. *Actualités Scientifiques et Industrielles 100. Exposés de Biologie Générale en rapport avec la Cytologie.*

By M. Dubuisson. Hermann et Cie, Paris. 12 francs. 10 x 6½; 47; 1934 (paper).

The hypotheses advanced to account for membrane potentials in living cells are discussed and the recent experimental work on the subject is briefly reviewed. The presentation is clear and concise and this booklet ought to be very useful to anyone beginning the study of this subject. There is a bibliography of 84 titles, most of them in English or German.

KREBS *im Lichte biologischer und vergleichend anatomischer Forschung. I. Band: Krebs im Ectodermgebiet.*

By Josef Lartschneider. Franz Deuticke, Leipzig and Vienna. 10 marks. 7⅞ x 5½; 192; 1934 (paper).

A study of the biology and comparative anatomy of cancer of the ectoderm. The author covers the research and the theories advanced in Germany and Austria thoroughly. There is a bibliography confined mostly to German titles, and an adequate index.

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 424. Methoden der Muskel- und Nervenphysiologie. Die Methode der Licht-Stromformung.*

By Ludwig Nicolai. Urban und Schwarzenberg, Berlin. 5 marks. 10 x 7; 89; 1934 (paper).

Lieferung 424 discusses the operation of photo-electric cells, both of the vacuum and of the selenium type, and describes vacuum tube amplifying equipment to actuate registering devices.

BIOCHEMISTRY

THE LYOPHILIC COLLOIDS (*Their Theory and Practice*).

By Martin H. Fischer and Marian O. Hooker. Charles C. Thomas, Springfield, Ill. $4.50. 9⅜ x 6¼; viii + 246; 1933.

Fischer and Hooker have collected the results of a long series of observations on the stability and the electrical conductivity of the colloidal mixtures of phenol and of soap with water in this book. Regarding these systems as models of living matter, and reasoning by analogy:

> The evidence presented, compels the conclusion that neither living matter nor any fraction of it is to be thought of primarily as a dilute solution or as anything approximating such a system. It is, rather, a protein to which the salts have been bound chemically (fundamentally as a base-protein-acid compound) and *in* which water has then been "dissolved" (or to which the water has been bound as a hydrate). This four part affair is to our minds the fundamental unit of the living mass. . . . .
>
> If the conclusion is accepted that all the water of the living mass is held in bound form it leads to an important corollary. The chemical reactions which occur in living matter must occur in a medium far different from ordinary water. *Living matter is normally a practically anhydrous medium; the chemical reactions characteristic of the normal life of the cell occur in an anhydrous medium and their course and products must, in consequence, be entirely different from the course and products of these same reactions occurring in and familiar to us from study of the ordinary aqueous solution.* (Italicized by the author.)

Fischer disagrees with a large number of physiologists on many other points, notably on the existence of semi-permeable membranes and on the rôle of osmotic pressure. The book is provided with an index.

AN INTRODUCTION TO BIOCHEMISTRY.

By William R. Fearon. William Heinemann (Medical Books), London. 10s. 6d. net. 8½ x 5½; x + 313; 1934.

In this introduction to biochemistry, planned to serve both as a textbook and as a laboratory guide, there is more emphasis than usual on the rôle of inorganic compounds in metabolism, and in viewpoint it is a little closer to physiology than to organic chemistry. Certain topics which require quantitative treatment and a background in biology in order to be presented effectively, such as the chemistry of blood, nerve, and muscle, are dealt with only briefly. The style of presentation and the selection of material are suited to college students beginning the study of

biochemistry, and the usefulness of the book as a laboratory manual is increased by numerous tables and diagrams of the color reactions and precipitation tests for important substances. There is an index and a short list of directions for the preparation of reagents.

PRACTICAL METHODS IN BIOCHEMISTRY.
By Frederick C. Koch. William Wood and Co., Baltimore. $2.25. 9 x 5⅞; vii + 282; 1934.

This manual is intended to introduce medical students to the important biochemical methods in current use and especially to familiarize them with the standard quantitative methods used for the study of body fluids. The explanations of the procedures are clear and detailed and the pedagogical value of the book is increased by discussion of underlying chemical principles involved in the analyses. There are numerous tables to facilitate computations and in an appendix about forty pages are devoted to directions for the preparation of reagents. This manual was written as a companion to Professor A. P. Mathew's textbook. It deserves a wide usage.

DIE HORMONE *ihre Physiologie und Pharmakologie. Zweiter Band: Schilddrüse. Nebenschilddrüsen. Inselzellen der Bauchspeicheldrüse. Thymus. Epiphyse.*
By Paul Trendelenburg. Julius Springer, Berlin. 45 marks (paper), 46.80 marks (cloth). 9½ x 6⅝; x + 502; 1934.

This, the last volume of a thorough and useful review of the literature of the hormones, treats those of the thyroid, parathyroids, pancreas, thymus, and pineal body. Upon the author's death in 1931 the publication of the manuscript was undertaken by one of his students, Dr. Otto Krager. He has changed the original manuscript only where more recent discoveries have made it necessary and has brought the literature up to the summer of 1933. There is an adequate subject index. The first volume of this work was noticed in these columns in Volume 5, page 121.

LE SÉRUM NORMAL: *Récolte et Caractères Physiques.*
By Denis Brocq-Rousseu and Gaston Roussel. Masson et Cie, Paris. 75 francs. 9⅞ x 6½; 363; 1934 (paper).

The authors have incorporated in this large volume the results of practically every study and observation made to date on the physical properties of normal blood serum. It is a most thorough compendium, clear and also critical; invaluable as a reference book. There is a bibliography of 57 pages.

TRANSPORTEURS D'OXYGÈNE. *Actualités Scientifiques et Industrielles 102. Exposés de Physiologie.*
By Marcel Florkin. Hermann et Cie, Paris. 12 francs. 10 x 6½; 44; 1934 (paper).

This is an excellent review of the results of recent research on the respiratory pigments of the blood. The first chapter discusses their chemical constitution; the second, their physiological action; and the third, their distribution throughout the animal kingdom. A bibliography of a hundred titles, mostly in English and German, concludes the booklet.

DIE SPEZIFIZITÄT DER SEROLOGISCHEN REAKTIONEN.
By K. Landsteiner. Julius Springer, Berlin. 8.80 marks (paper); 9.80 marks (cloth). 9½ x 6½; iii + 123 (1933).

This is a useful brochure giving a summary of the work of the distinguished author and others on the antigens and phenomena of serological specificity, principally from the chemical point of view. It is amply equipped with bibliographies—general text-books, summaries and bibliographies,

lengthy literature lists on specific phases following each chapter, and works which have been published while this book was in press. An adequate index adds to the usefulness of the work.

FUNDAMENTALS OF BIOCHEMISTRY *in Relation to Human Physiology. Fourth Edition.* *By T. R. Parsons. William Wood and Co., Baltimore.* $3.00. 7¼ x 5; xii + 435; 1933.

Parsons' introduction to biochemistry remains the most interesting book on the subject available to beginners and interested laymen, and the fourth edition, brought as nearly up-to-date as is possible in such a rapidly growing subject, retains the narrative form that made the earlier editions so readable.

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 427. Allgemeine und vergleichende Physiologie. Analysen von Gasgemischen. Gasometrische Methoden zur Analyse von Blut und anderen Lösungen.* *By John P. Peters and Donald D. van Slyke. Urban und Schwarzenberg, Berlin.* 16 marks. 10 x 7; 322; 1934 (paper).

Lieferung 427 has been translated from Volume II of the same authors' *Quantitative Clinical Chemistry*, and for the most part deals with the methods they elaborated for the analyses of blood gases.

DAS VERHALTEN VON BLUTKÖRPERCHEN SOWIE VON MIKROBEN IN ABGESTUFTEN ESSIGSÄURE-VANADATGEMISCHEN. *Eine biochemische Methode zum Studium der Artspezifität.* *By H. M. Jettmar. Urban und Schwarzenberg, Berlin and Vienna.* 3 marks. 9½ x 6¼; viii + 121; 1934 (paper).

A detailed presentation of the technique and results of the Oldeman-Bendien reaction on sera, blood corpuscles and microbes. Biochemists and microbiologists will find it a useful handbook.

SEX

THE ETHICS OF SEXUAL ACTS. *By René Guyon. Translated from the French for the first time by J. C. and Ingeborg Flugel. Alfred A. Knopf, New York.* $4.00. 8⅝ x 5⅞; xxii + 383 + xxvii; 1934.

M. Guyon is both a Frenchman and a hedonist. As a Frenchman he follows to their logical conclusion the principles which as a hedonist he professes. The Judeo-Christian ethics to which the Western world pays at least lip-service, true to its ascetic postulate of the vanity of this world, condemns sexual pleasure except for a grudging concession of the legitimacy of intercourse—for purposes of reproduction only—between a man and a woman over whom a magical formula has been recited. M. Guyon on the other hand concludes that sexual pleasures, including the so-called aberrations, are no more "immoral" than the pleasures of the table. His travels in the Far East have convinced him that a society which permits a free gratification of sexual desires is far happier and less neurotic than one which taboos them. The psychiatrists, he concludes, instead of basing their criteria of sexual normality on an objective, physiological foundation, have tacitly assumed that whatever is contrary to the local mores is pathological. Their attitude is thus not that of scientists, but of conventional moralists masquerading as scientists.

But psychiatry has gone even further than this in its abject and unconditional surrender to taboo. Without any attempt at verification it has accepted at their face value many of the prejudices and superstitions which have resulted from taboo. There exists a whole group of neuroses based upon fantastic and utterly unscientific notions: quite a considerable portion of humanity lives and has its being in a world that is peopled by illusory and imaginary entities—gods, prophets, saints, angels, devils, demons, ghosts—with whom they have daily converse, whom they call upon for help or counsel, whom they bribe or curse or worship, for whose sake they are ready to ruin both themselves and their families. Here, then, there is a formidable neurosis, which (unlike the manifestations of sex) is incapable of explanation in terms of normal, natural, easily verifiable, healthy processes. It is a neurosis that has sprung fully armed from its parent, the human brain. A triumph of artifact, it yet eludes the probing analysis of the psychiatrists, and almost entirely escapes their disapproval, pitiless as this may be in other directions. . . . So discreet a choice shows the measure of

confidence that we may have in the pronouncements of this science!

This is a book well worth reading and pondering, whether one is finally convinced by it or not. There seem to us under present conditions to be two objective reasons for limiting one's sexual pleasures. The first, briefly mentioned by M. Guyon, is that in a world where venereal diseases are fairly widespread the danger of infection from free intercourse is by no means negligible. The second, which he does not mention—no doubt he will deal with it in the sequel to be devoted to the question "as to what kind of organization, public and private, would appear best to meet the legitimate demands of sexual liberty"—is that so long as sexual pleasure sometimes leads to reproduction the care of the children produced must somehow be provided for. In an economic organization where the male has the upper hand the father of the child is the natural person to charge with this responsibility. But, as Strindberg pointed out, it is a wise father who knows his own child. The custom of chastity is therefore not a mere taboo but has the rational function of fixing at least the probable paternity of a child. However, with more effective and better known techniques of venereal prophylaxis and contraception these objections to free sexual expression will vanish. It is a striking testimony to the validity of much of M. Guyon's criticism that many of the clergy and other professional guardians of our conventional morality oppose venereal prophylaxis and contraception on that very account.

THE CASE FOR POLYGAMY *or The Case Against the System of Monogamous Marriage. By J. E. Clare McFarlane. The Search Publishing Co., London.* 5 shillings net. 7¼ x 4⅝; 159; 1934.

This book is not so much *for* polygamy, as usually understood, as it is *against* monogamy. Its essential idea is that there are too many old maids in the world, especially in England, and that something ought to be done about it. If the right thing is done then both the women and the men will be satisfied, and that will make it unanimous all around. The author is a deeply religious and poetical fellow, filled to bursting with the zeal of the uplifter. His arguments are extremely persuasive, and he draws support for them from the Bible with a skill matched only by such great theologians as Bishop Cannon and Brother Bryan of revered memory. But, alas, when he comes to the compounding of his eye-wash which is to cure the dreadful disease that festers in the body social, of which the etiological agent in his view is monogamy, his naïveté is positively shocking. For what he proposes, in all seriousness, is this:

> Let each woman have the right to make an alliance *with the man of her choice* if he will have her and (if he be already married) provided his wife agrees to the arrangement. The value of this provision will be three-fold: it will indicate that the bond of love between husband and wife is so secure that the latter can with confidence permit another woman to share his affections; it will indicate also that the man is big enough to be entrusted with the affections of another woman; and it will ensure that prior to such an arrangement the women concerned have reached a basis of mutual understanding and confidence. . . . .
>
> Let each woman, therefore, be in a position to exercise, if she so desires, lawfully and without reproach, the function of motherhood for which Nature has endowed her. Let the stigma of illegitimacy be abolished from social life, and the children of every woman be accorded equal rights and recognition.

If there ever existed a freshman student of biology who did not sometime think of this scheme as an ideal solution of the problems of human behavior consequent upon the outpouring of gonadal hormones, we never heard of him. But later on in life he learns, even before his honeymoon is over, that noble as the idea seems to be there is a flaw in it. We think that Mr. McFarlane quite honestly does not know what that flaw is. If he *wants* to know he has only to ask any married woman. She'll tell him! And how!

THE SINGLE WOMAN. *A Medical Study in Sex Education. By Robert L. Dickinson and Lura Beam. The Williams & Wilkins Co., Baltimore.* $5.00. 9 x 5⅞; xix + 469; 1934.

While this is primarily a medical study of

certain phases of human fertility it is much more than a study of physiology and anatomy. It deals with the psychology of the patient, her emotional life, her conflict and her refuges from that conflict. Something over a thousand case histories make up the study which forms the second volume in a comprehensive investigation on sex experience and behavior. The work concludes with a brief summary and an appendix containing an arrangement of the material in tabular form. Tables of two control groups are included. The volume is indexed.

MORE LOVE AND SEX.

By X. Ray. The C. W. Daniel Co., London. 1 shilling net (paper); 2 shillings net (cloth). 7¼ x 4¾; 64; 1934.

This book, a sequel to the author's *Love: An Outspoken Guide to Happy Marriage* noticed in Volume 8, page 378 of this REVIEW, is a collection of detached thoughts and quotations, emphasizing the importance of a soundly biological attitude towards sex and the economic and traditional difficulties in the way of its attainment. There are a bibliography of one page and an index.

LE DEVENIR DU SEXE. *Actualités Scientifiques et Industrielles 78. Exposés de Biologie (Embryologie et Histogenèse).*

By Vera Dantchakoff. Hermann et Cie, Paris. 15 francs. 10 x 6¼; 60; 1933 (paper).

A good summary of the present state of knowledge concerning the morphogenesis of sex.

BIOMETRY

AN INTRODUCTION TO STATISTICAL ANALYSIS.

By C. H. Richardson. Harcourt, Brace and Co., New York. $3.00. 8½ x 5⅝; xi + 285; 1934.

This excellent text deals with tabular and graphical representation, measures of central tendency, measurement of dispersion, skewness, excess, moments, linear trends, simple correlation (approached through the concept of regression), nonlinear trends, curve fitting, permutations, combinations, probability, the point binomial, the normal curve and the theory of sampling. Numerous exercises, an annotated list of books for supplementary reading, a four-place table of areas and ordinates of the normal curve and an index are also given. Since Professor Richardson feels that the student "will not comprehend fully what a formula means and what are its limitations unless he knows whence it comes and what are the assumptions underlying its development" he includes many derivations that do not presuppose a knowledge of more than high school algebra. However, many biologists and physicians shy like a skittish horse at any formula which appears at all complicated, however elementary it may be in reality. We fear that one glance at the Σ's in some of his formulas would send such students galloping to the tall timber, from which it might be difficult to lure them back into the classroom.

CALCULATION AND INTERPRETATION OF ANALYSIS OF VARIANCE AND COVARIANCE.

By George W. Snedecor. Collegiate Press, Ames, Iowa. $1.00. 7½ x 5⅛; iv + 96; 1934.

An attempt is made here to clear up the technique of R. A. Fisher's known as the "analysis of variance." This is a very elementary calculator's hand-book with brief explanations, discussions, and notes on theory. The arithmetic examples are easier to follow than are Fisher's, but the method and terminology are the same. The author specifically states that the objective of the method is "the separation of the gross variation of the entire sample into two portions: (i) the variation among the means of the classes, and (ii) an average of the variation within the several classes." Yet the examples given use the "between class" variance as a test for homogeneity and not as a measure of

variation between means of classes. This is the same discrepancy between problem and illustration that exists in Fisher's work.

MANUALE DI STATISTICA. *Introduzione allo Studio Quantitativo dei Fatti Sociali. Volumes I and II.*

By Felice Vinci. Nicola Zanichelli, Bologna. 25 lire per volume. 10 x 7; Vol. I, vii + 230; Vol. II, 303; 1934 (paper).

A textbook of mathematical statistics written for students of social sciences who have only a limited knowledge of higher mathematics. It is very well done and praiseworthy are the elegant algebraic demonstrations, in particular those relating to the theory of probability. Credit for the latter should be given to Castelnuovo and Cantelli whom the author follows.

In appendices are given many useful tables, a chart showing the evolution of statistics (taken in part from Pearl), a list of statistical societies and journals, etc. There is an index.

VARIABILITY IN WEIGHT IN THE GOLDEN-CROWNED SPARROW. *University of California Publications in Zoology, Vol. 40, No. 5.*

By Jean M. Linsdale and E. L. Sumner, Sr. University of California Press, Berkeley. 9¼ x 6¾; 11; 1934 (paper).

PSYCHOLOGY AND BEHAVIOR

THE EFFECTS OF MUSIC UPON PULSE RATE, BLOOD-PRESSURE AND MENTAL IMAGERY.

By Alec Washco, Jr. Temple University, Philadelphia. $1.00. 9 x 6; 269; 1933 (paper).

Thirty adolescents have been subjected to an experiment to determine the influence of different types of music on systolic blood pressure, on pulse rate and mental imagery. The principal conclusions reached are that music of the type of a march, rhapsody or overture stimulates blood pressure and pulse rate, while a waltz, serenade or intermezzo causes a decrease. A survey of the tables shows that this is arithmetically true and possibly statistically, but there arises a doubt as to its significance. On the average the maximum increase observed is 10.4 mm. for blood pressure while that of the pulse rate is 8.9 beats. The maximum average reduction of blood pressure is 8.4 mm. and pulse 8.03 beats. Without adequate experimental control these and similar reported results obviously cannot be accepted, though they satisfy popular conceptions and appear true in individual cases.

The author is apparently a believer in the therapeutic value of jazz, for of the Rhapsody in Blue he writes: "This music suggests a treatment for Melancholia, anxiety and other forms of depression. It seems to react as a safety valve for depressed and suppressed nerves. It is one aid to the resolution of mental conflicts and at least temporarily alleviates worries." There is an extensive bibliography but no index.

TEXTBOOK OF ABNORMAL PSYCHOLOGY.

By Roy M. Dorcus and G. Wilson Shaffer. Williams & Wilkins Co., Baltimore. $4.00. 9 x 6; xiii + 389; 1934.

In 360 pages of text the authors attempt a complete review of the literature regarding the anatomy and physiology of the special sense organs, general neurology, psychology, psychiatry and psychotherapy. Useful as a textbook, the necessity for condensation results in generalized definitions and statements which at times may appear incorrect. On page 37, for example, one notes: "Among the symptoms of pathology of the vestibular sensations may be listed: *absence of nystagmus*, continuous nystagmus . . . ." That this obvious *lapsus linguae* should have passed unobserved by one of the authors who has contributed special studies on the subject is surprising.

Worthy of special mention is the critical attitude that the authors have maintained in the exposition of the several psychological theories, though they are frankly disciples of Knight Dunlap. There are a bibliography of 313 titles and name and subject indices.

THE NATURE AND TREATMENT OF AMENTIA. *Psychoanalysis and Mental Arrest in Relation to the Science of Intelligence.*

By L. Pierce Clark, Assisted by the Staff of the Psychoanalytic Sanatorium at Rye, N. Y., T. E. Uniker, Ethel L. Rourke, W. K. Cushing, Margaret C. Cairns. William Wood and Co., Baltimore. $4.25. 9 x 6; xv + 306; 1933.

The author, well known as a psychiatrist, has been a valuable contributor to studies on the mentally deficient. In this volume he discusses the energies which have to do with the ament's (the mentally subnormal individual) immediate problem of coping with his outer world. A number of case histories are given in detail to show "the nature of the psychic barriers tending to impoverish mental growth, to indicate how these emotional fixations have come about, and to formulate their direct connection with mental arrest." Suggestions are made regarding the establishment of a sounder training treatment for the feebleminded. On the basis of psychoanalytical findings the author believes that much can be learned in guiding the ament in the choice of his environment, his education and his future occupational activities. The work includes a glossary, a list of references and an index. Dr. Ernest Jones contributes a foreword.

A NEW PHYSIOLOGICAL PSYCHOLOGY.

By W. Burridge. William Wood and Co., Baltimore. $3.00. 7¼ x 5; vii + 158; 1933.

Basing himself on his experimental study of the rhythmic tissues of the heart Professor Burridge applies the theory of rhythmic action to the central neurons and sensory end-organs, and attempts to correlate these processes with mental phenomena. In this way he arrives *inter alia* at a physiological formulation of Freudianism. Such deductions as his explanation of John Citizen's attitude to his wife in terms of the intensity and rate of neural rhythm may seem fantastic, but we must not forget that much of the physiological psychology of the more complex mental processes is still a matter of inference. If no one has observed the rhythm of a brain cell, it is equally true that no one has seen it explode. There is a bibliography of 25 titles and an index.

INDIVIDUAL PSYCHOLOGY, PSYCHIATRY, AND HOLISTIC MEDICINE.

By J. C. Young. The C. W. Daniel Co., London. 2s. 6d. net. 8½ x 5½; 62; 1934 (paper).

This little book consists of two papers delivered before the Medical Society of Individual Psychology, London, an organization devoted to "tempering the robust wind of Individual Psychology to the shorn and somewhat fearful lamb of modern medical practice." The gist of them is that laboratory technique, however elaborate, cannot take the place of insight into the patient as a whole. Unfortunately, since laboratory technique is easier to learn than insight, Dr. Young may have difficulty in converting the average medical practitioner.

STORIES OF SECOND-SIGHT IN A HIGHLAND REGIMENT.

By William Kirk. Eneas Mackay, Stirling, Scotland. 2s. 6d. net. 7⅜ x 4⅛; 123; 1933.

A collection of often weird, sometimes humorous stories, dealing (so 'tis said) with the personal experiences of Highland soldiers, comprises the present volume. Whether or not the yarns are true does not detract from the fact that some of them are interesting.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

AN INTRODUCTION TO LOGIC AND SCIENTIFIC METHOD.

By Morris R. Cohen and Ernest Nagel. Harcourt, Brace and Co., New York. $3.50. 8½ x 5⅝; xii + 467; 1934.

This admirable text aims to "find a place for the realistic formalism of Aristotle, the scientific penetration of Peirce, the pedagogical soundness of Dewey, and the mathematical rigor of Russell," and, we should say, succeeds very well. The authors agree with the traditional view of logic as the science of valid inference rather than as the study of how the mind works. In the treatment of necessary inference both the Aristotelian and the symbolic techniques are used. In the chapter on probable inference the authors reject the interpretation of probability as a measure of belief and adopt Peirce's interpretation of probability as the truth-frequency of types of arguments. The function of hypotheses and classification in scientific method is considered. Mill's methods of experimental inquiry are found to be neither methods of proof nor methods of discovery of relevant factors but are of value in eliminating irrelevant factors. The distinction, which the authors emphasize in their discussion of measurement, between additive characters such as weight and non-additive characters such as intelligence, which can only be ranked in a certain order, is one which is too often forgotten. In the chapter on statistical methods we have only two exceptions to enter: (1) While it is of course true that the computer cannot improve the accuracy of an arithmetic mean at will by carrying more decimal places it is *not* true that "the precision which is a result of numerical computation is fictitious unless the observations have been made with the same degree of precision." The errors of the individual observations will rarely be all in the same direction and consequently the mean of a large number of observations will usually be more precise than the individual observations on which it is based. (2) While the median is more stable than the mean for many leptokurtic distributions, for normal and platykurtic distributions the mean is the more stable average.

Exercises, suggested readings and an index are given. Altogether this is an excellent book.

MODERN BREWING (*Second Edition*). *A Practical Hand Book of Contemporary Brewing Practice.*

Written and published by Carl A. Nowak, Chemical Bldg., St. Louis. $10.00. 9 x 5⅝; 389; 1934.

Mr. Nowak is a practical brewer whose aim is to explain brewing practice and the scientific principles on which it rests for the benefit of an industry that is relieved to find itself respectable again, and that is conscious of the lack of textbooks. His book is built around a translation of Heinrich Luers' *Grundriss der Bierbrauerei* which sets forth the fundamentals of beer brewing as practised in Germany and which provides the theoretical explanation for the fermentation processes. This is only the foundation, as it were. "For those not familiar with the methods of doing business in the United States, it may be well for me to call attention to the fact that, whatever the American does, is on a large scale, usually well financed, but must be done in a hurry. This accounts for many of the strange processes which the reader will find in subsequent pages of this book." (Probably this accounts for some of the strange tastes of the product, too.) Besides this odd disposition of the American business man there are a number of peculiarities of the American taste in beer to harass the brewer. For one thing, Americans insist on drinking their beer much colder than Germans or Englishmen, not only losing the aroma the *Braumeister* has worked hard to put there but subjecting the beer to risk of turbidity. Now this would not be such a serious matter if Americans did not also have the barbarous custom of drinking beer from glass vessels instead of from opaque mugs in use on the Continent, and that makes it necessary to brew for optical properties as well as taste. American-grown barley has too much protein to yield the proper

shade of light beer unless to its malt is added some other carbohydrate. It is interesting to note that companies processing corn products showed more willingness to develop materials of this kind during Prohibition than they ever did before. Brewing beer in this country is a different thing from brewing on the Continent. Besides describing trade practices in this country the book is intended to teach the bare fundamentals of chemistry and bacteriology to brewers and their assistants. The book is provided with glossary, bibliography, index, and tables of various sorts.

MADEIRA. *Wine, Cakes and Sauce.*
By André L. Simon and Elizabeth Craig. Constable and Co., London. 5 shillings net. $7\frac{3}{8}$ x $4\frac{3}{8}$; 153; 1933.

SHERRY. *With an Appendix on Shippers and a Folding Map.*
By H. Warner Allen. Constable and Co., London. 5 shillings net. $7\frac{3}{8}$ x $4\frac{3}{4}$; 117; 1933.

These two volumes inaugurate a new series —*Constable's Wine Library*—likely to be of great value and interest to everyone concerned with the finer aspects of civilized living, provided the standard set by these initial volumes can be maintained.

Warner Allen has already a firmly grounded reputation as an expert on wines, and *Sherry* will further enhance it. It is the best treatise, considering the limitations imposed by its size, known to us on that greatest of high-powered wines. It is not a rhapsodical eulogy of a glorious beverage, but a pleasantly written, thoroughly erudite, technical scientific treatise on sherry, telling its history, how it is made, its varieties, etc. In short it is precisely the kind of book that will inform and entertain a person who wants to acquire a really sound elementary knowledge about sherry.

Almost exactly two-thirds of *Madeira* is devoted to recipes for cooking in which that wine is used, and for the accessories useful in giving Madeira parties instead of cocktail parties. For this part Elizabeth Craig is responsible. Wives of biologists (as well as of other gentry) will find this part of the book extremely useful and in good part novel. The first third of the book, by Simon, is essentially a brief history of Madeira wines. It is entertaining enough, but of a literary rather than a scientific flavor.

THE SYSTEM OF BASIC ENGLISH.
By C. K. Ogden. Harcourt, Brace and Co., New York. $2.50. 8 x $5\frac{3}{8}$; ix + 320; 1934.

With increasing international exchange of ideas the need for an international language becomes greater. In forty years Esperanto has got no great support, while English has become the most widely used of languages. Basic English is a system of 850 English words, to take care of all the needs of everyday living and for use as an international language for business, radio and science. It is a complete language which may be learned in a month. Important men of learning and of science in every country on earth give it support. This book gives an account of the system and examples of its use in everyday talk, in radio, newspapers and motion pictures, in business, in science, in economics and political questions, in religion, and in stories. The present account is in Basic English.

LOGIC IN PRACTICE.
By L. Susan Stebbing. Methuen and Co., London. 2s. 6d. net. $6\frac{3}{4}$ x $4\frac{1}{8}$; ix + 113; 1934.

This excellent little book is, as the title implies, concerned with the practical technique of sound reasoning. While a brief, but clear, discussion of logical forms is given, equal attention is paid to the symbolic character of language and the danger of ambiguity in the use of the symbols. From the frequency with which Mr. Roosevelt replaces Socrates in the examples the reader may draw the probable inference that the English find the New Deal a subject of interest. A brief bibliography and an index are provided.

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